Landscape series: 4

The suburbanization of the Aruban landscape

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"

2016

"We must spare no effort to free all of humanity, and above all our children and grandchildren, from the threat of living on a planet irredeemably spoilt by human activities, and whose resources would no longer be sufficient for their needs".
—United Nations Millennium Declaration (2000) —

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This paper is part of a series on the developments that relate to the Aruban landscape. To bring perspective to current environmental threats and developments good knowledge of present, but also of past spatial processes is vital.
We show in this paper how the extent of early 20th century Cunucu landscape in Aruba followed the contours of the geological substrate and past human action and how these agricultural developments shaped the layout of today's trends in suburbanization. We will go into detail and explain the shift in the location of new construction and infrastructure over the last hundred years. In an example we explain how some geological and past topographical features have influenced the development of infrastructure and housing today.

This study is also an example of how we can use GIS[1] methodology to study spatiotemporal patterns in combination with the use of historic maps in Aruba. The aim of this study is to inform and give insight in the long-term consequences of change. A more general aspect of this study is to help us grasp a larger perspective and learn to comprehend, similar to what we describe in this study, how current change in nature and habitats will define the future opportunities to exploit the landscape and its intrinsic values.

The historical perspective

The changes in the landscape over the last century went at a very fast pace. At the end of the 19th century, the landscape was already characterized by quite open panoramas (Teenstra, 1837) due to over two centuries of intense harvest of woods and grazing by herds (Hartog, 1953). In late 19th century, following new impulses to the economy, initiatives were taken to stimulate agricultural subsistence (Ridderstaat, 2007). Several cultivation projects took place on the more fertile soils in the land interior (San Barbola) and on the more nutrient-rich fluvial beddings near the coast (Savaneta). Consequential to the success of these projects (Alofs, 2015, pers. com), in just a few decades, at the turn of the 20th century, most of the 'arable' land was already developed for mixed farming and Aloe cultivation (Werbata, 1913). The exploitation of the Aruban countryside by farming, the breeding of goats, sheep, poultry, pigs and cattle and the cultivation of a variety of (local) vegetables and fruits, lasted for over half a century. The typical countryside with open panorama's, grazing livestock and farmland improved local living conditions considerably and is passionately called the *Aruban Cunucu*. The climatic circumstances and poor soil conditions made agricultural subsistence harsh, however.

Following the discovery of large oil fields in neighboring Venezuela, the oil processing industry was introduced in Aruba. Soon after each other, in about 1929, two oil refinery installations were accomplished, one in San Nicolas and one near Oranjestad. To make both ends meet, it was already common that, seasonally, Aruban farmers would leave their fields and went to work abroad, for instance to assist in the harvest of sugarcane in Cuba or in Venezuela. But with the new opportunities in the upcoming industries, the economic prospects of Aruban farmers changed as well. Soon farmers decided to leave their traditional agricultural subsistence and either went to work abroad or in the oil refineries of San Nicolas and Oranjestad. In the years that followed, and in particular during World War II, a service- and facilitation-industry developed in Aruba as more immigrant workers from neighboring Caribbean Islands had come to work and stay in Aruba. With the growth of the economic developments in Aruba, the number of workers in agriculture went down from an initial 1,281 agricultural livelihoods in 1908 to 736 in 1924 (Kelly, 1999; reference in Ridderstaat, 2007, Table 4, pp 18). Actually, in 1912, 14% of total population (1,337 workers) was officially registered in agriculture (Benjamins & Snelleman, 2015). In the years that followed, crop fields were left more and more abandoned as farmers went to work in San Nicolas and Oranjestad.
Initially, the farmers' family kept the agricultural subsistence running but soon the farmland was left completely and wildered. The once well-maintained agricultural countryside and the typical Cunucu scenery with small houses and stone walled corals or cacti fences slowly disappeared. Those who could afford it exchanged their small cunucu house for the more appealing modern American-style housings (Bakker & Klooster, 2007).

The agricultural exploitation of the *Cunucu* landscape, thus, didn't last for long. In less than half a century most of the former cunucu turned into what is locally called a *Mondi*[2]. For some time, the Mondi developed in its own natural course of abandonment. Nature was at the brink of reestablishment on the open fields when the land was again in new demand, now for the housing of a growing population and the expansion of economic activities. In only a few decennia most wildered terrains became parceled and the vegetation regrowth was cleared for new construction. Today again the economic development and urbanization spreads over large parts of the island. Local nature is under pressure, once again (Barendsen, et al., 2008).

We have come to the point that a majority now realizes that we have to protect the remaining natural values (Aruba, 2011) and that there were limits in the way that growth took shape. Worldwide, the conviction has taken shape that the remaining natural environment plays an imminent role in the health of local living conditions and is important for economic development (The World Bank, 2010). A number of threats already receive regional attention as they appear to be building. Some of the major harms that are known to play a role in the deterioration of environmental health conditions are eutrophication of marine and fresh waters (Lapointe & Mallin, 2011), (Gast, 1998) (Haapkylä, Ramade, & Salvat, 2007), marine and land pollution (Bak, 1987), chemical health disrupters (EEA, 2012), exotic pests (van Buurt & Debrot, 2012), (van der Burg, de Freitas, Debrot, & Lotz, 2012), and the loss in natural habitat and landscape [(Del Nevo, 2008), (Baker, Glynn, & Riegl, 2008)].

[1] A GIS (Geographic Information System) is a computer-based tool that enables the linking of information from many different fields on the basis of a common geographic component. Layers with information from for instance, socioeconomic, environmental and topographic surveys can be brought together and analyzed on a common spatial scale. Linked in this manner, the GIS system provides additional information and opportunities for research.

[2] Wildered countryside

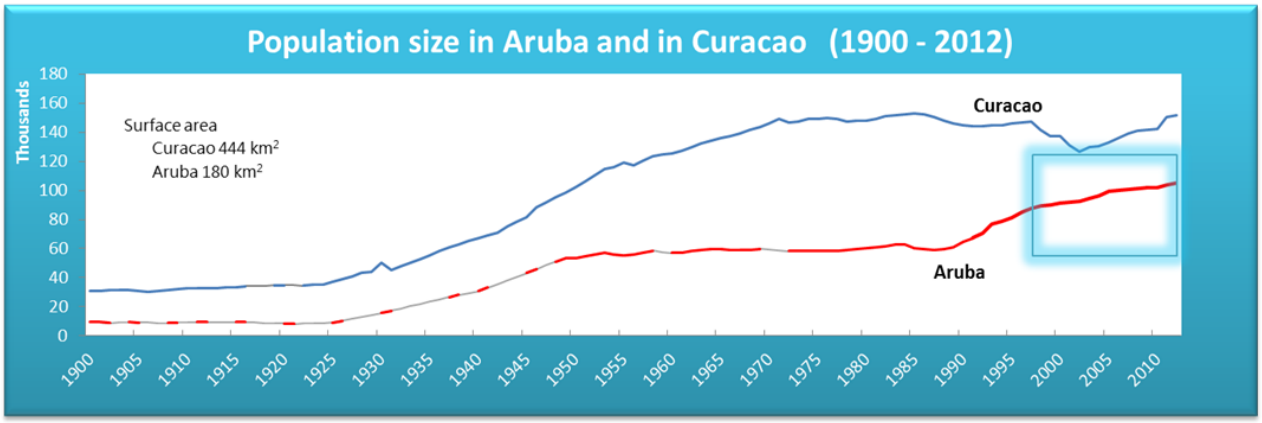


Figure 1 Comparison between population estimates in Aruba and in neighboring Curacao over the last century.
Source[3]: Population Registry Office Aruba, CBS Aruba and Curacao.
Note[4]: The period highlighted by the blue square (1998-2010) denotes the period on which further analyses is conducted for the purpose of this paper. To make the graph visually more appealing, we added the missing data points with simple arithmetic interpolation (indicated by the gray-colored line segments).

Population growth

Between 1930 and 1950 population growth was intense due to the booming oil industry (see figure 1). After the very profitable years during WWII, the oil industry, however, had to economize its production facilities because competition was fierce. The Arend Oil Company near Oranjestad had to close its doors in 1953 and the Lago Oil refinery in San Nicolas was forced to modernize and downsize its workforce.

During the years that followed, the population size in Aruba didn't change much, up until the 80's. After many years of a stable economy but without the desired economic growth, political aspirations had taken shape to separate from the former Dutch Antilles and attain a financial as well as administrative equal political position within the Dutch Kingdom. In 1986, Aruba became an independent state within the Dutch Kingdom under the so-called '*Status Aparte*' (Alofs L. , 2006).

Meanwhile, driven by the economic progress in Europe and the US, a tourism industry developed that offered new opportunities in the region. A growing number of travelers in Europe had money and interest to explore and visit the Dutch territories west of the Atlantic. With the boom in the tourism industry, drastic changes took place in the landscape. The face of coastal regions changed with the construction of Hotels, a facilitation industry and many residential areas to house the new immigrant workers. Population numbers grew once again drastically in Aruba.

In just a single century, the number of inhabitants ten-folded from about *9.700* in 1900 to *91,064* in 2000. After the first period of growth after WW II, in 1948, the population was estimated at *51,110* inhabitants. Then, after a period of stagnated economic and population growth, from the 90s onwards, the population numbers almost doubled in nearly three decades (from a short-term low of *58,873* inhabitants in 1987 to an estimated *110,108* in 2015).

Subsequent Census records show a population growth from *56,910* in 1960, *58,189* in 1972 to *60,866* individuals in 1981. The second impetus in growth started in the late 80s. Census records counted *67,382* persons during the 1991 Census, *91,064* in 2000 and *101,918* persons in 2010. Population growth continued until this day (Figure 1).

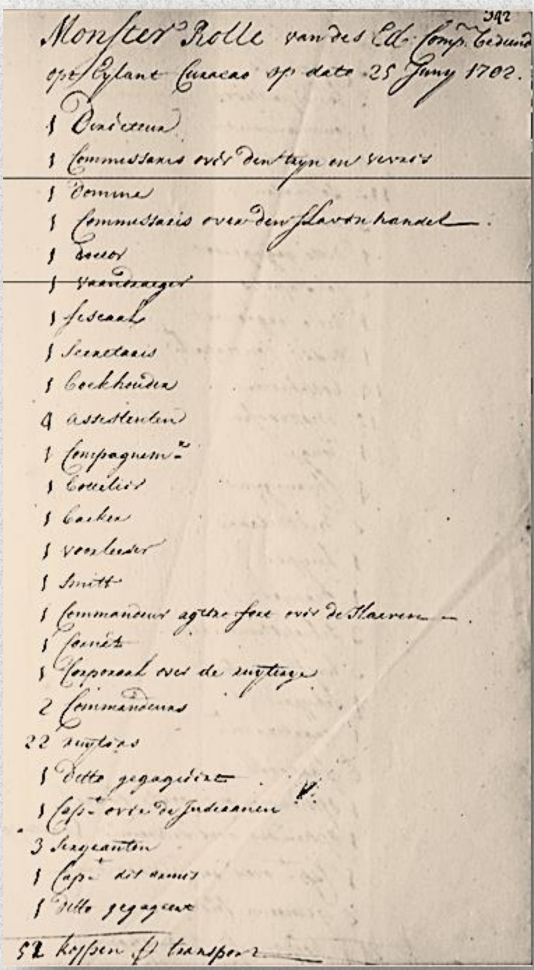
The consequences of the unremitting population growth reveal themselves in the landscape and influence the local living conditions of the small island community. An unbalanced fragmentation and loss of typical habitats and species will pose a challenge for socio-economic developments, however (EEA, Landscape fragmentation in Europe, 2011).

From the start of civilization, the Aruban landscape had transformed from a mostly wooded landscape (Hartog, 1953) into its current state of *suburban sprawl*. But strong data about the situation in the past and the changes up to now are lacking and can only be derived from incidental reports and former historic maps.

We review the more recent changes in the economy and the home living conditions in the next section, and discuss a number of indicators that are common to describe the economy. This is possible, as from 1998 onwards a well-established system with annually comparable statistical data reports exists. So, we used the year 1998 as the reference year for the description of subsequent changes from then on.

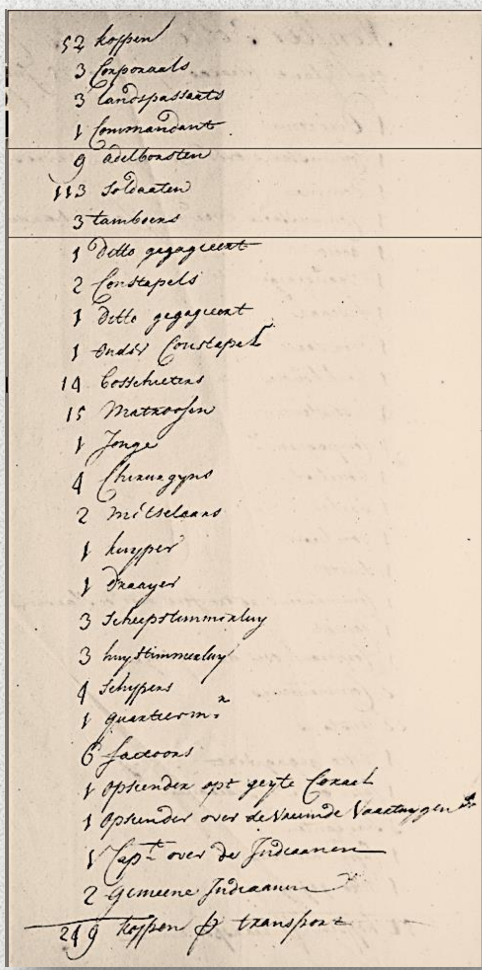
[3] The data of 1900, 1904, 1908-1911 is from: Herman Daniël Benjamins en Joh. F. Snelleman, '*Encyclopaedie van Nederlandsch West-Indië*'. Martinus Nijhoff/E.J. Brill, Den Haag/Leiden 1914-1917; Source in: www.dbnl.org (Digitale Bibliotheek voor de Nederlandse Letteren) under the auspices of the National Library of the Netherlands (Koninklijke Bibliotheek).

[4] In 1702, WIC documents mention only 5 colonists in Aruba, respectively 1 commander, 2 nurses and 2 soldiers (see the scanned documentation in Photo Series 1, pp. 5). There are no records about how many natives lived on the island at the time, but there may have been only few left to herd the cattle and horses and to harvest the logwood

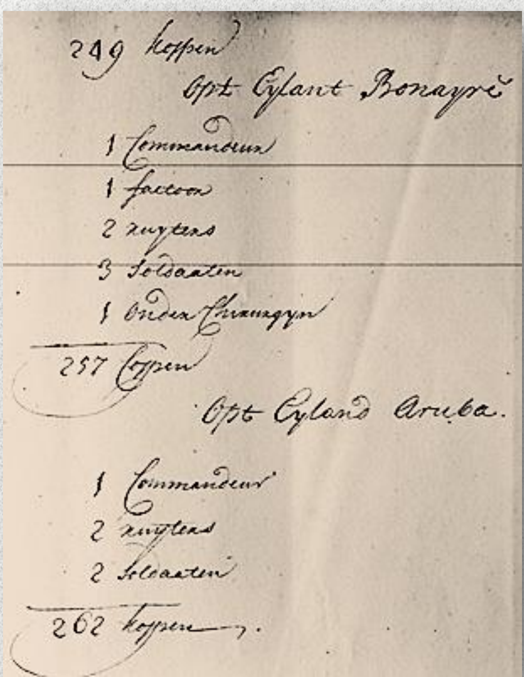


Monster Rolle van des Ed. Comp. bedienden
opt Eylant Curacao op date 25 Juny 1702.

1 Directeur
1 Commissaris over den tuyn en vivres
1 Domine
1 Commissaris over den slavenhandel.
1 doctor
1 Vaandrager
1 fiscaal
1 Secretaris
1 boekhouder
4 assistenten
1 Compagnon
1 Coutelier
1 backer
1 voorleser
1 Smitt
1 Commandeur agtersee over de slaeven.
1 [illegible]
1 Corporaal over de zuytlegs
2 Commandeurs
22 zuytlers
1 Dito gegagiert [illegible]
1 Capt. over de Indiaanen
3 Sergeanten
1 Capt. der armes
1 Dito gegageert
52 koppen p. transport



52 koppen
3 Corporaals
3 Landspassaats
1 Commandant.
9 adelborsten
113 Soldaaten
3 tamboers
1 Dito gegageert
2 Constapels
1 Dito gegageert
1 Onder Constapel
14 bosschieters
15 Matroosen
1 Jonge
4 Chirurgyns
2 metselaars
1 kuyper
1 draayer
3 Scheepstimmerlieden
3 huystimmerlieden
4 Schippers
1 quartiermr.
6 facteurs
1 opziender opt zoute Coraal
1 opziender over de Vaarende Vaartuygen &
1 Capt. over de Indiaanen
2 gemeene Indiaanen
249 koppen p. transport



249 koppen
Opt Eylant Bonayre
1 Commandeur
1 facteur
2 zuytlers
3 Soldaaten
1 Onder Chirurgyn
257 koppen
Opt Eyland Aruba.
1 Commandeur
2 zuytlers
2 Soldaaten
262 koppen.

Photo series 1
First count of WIC personnel in Curacao, Aruba and Bonaire on June 25, 1702 by local WIC Commander (see next page).
*Source: WIC documents of 1702 by the Cactus project **www.dpp-cactus.com**. Digital Preservation Project, scans v200: 342, 343. Dutch 'National Archive' under auspices of the Ministry of Education, Culture and Science in the Netherlands **www.nationaalarchief.nl***

Recent GDP

The GDP[5] (*gross domestic product*) is commonly used as an indicator for economic well-being and expresses the total market value of all goods and services produced in a country in a given period of time. Another measure, the *real (calculated) GDP per capita,* also takes into account the *purchase power* deflated for price increases[6]. In Figure 2 we present, relative to 1998, the population dynamics and the changes in 'real GDP per capita at constant 2010 prices' in Aruba, in between 1998 and 2013. The measure somewhat fluctuates over the years, but not dramatically, until 2009, when we observed a drastic downfall in spending capacity. Thereafter, the measure remained at a new, but lower level. Over the same course in time, the population size maintained a steady growth.

Today, the tourism industry has become the major pillar of the Aruban economy, in particular since 2012 when the Oil refinery closed its doors. Figure 3 shows that there has been a doubling in number of Cruise passengers during the final years of the last millennium, but that since then the increase in Cruise tourists has dampened and tends to fluctuate. The number of stay-over visitors also shows some fluctuation, but overall, a slow increase of 20% is observed over a 12 year period. Following the continuing expansion of the hotel and timeshare accommodations along the coast, in particular along the northwest coastline, many new establishments opened their doors. Interesting is the time period after 2007 when there was a drop in local purchasing power, yet a rise in 'Stay-over' and 'Cruise' tourists. The small economy in Aruba is dependent on the economies in large export countries and these had difficulties in maintaining progress during the years of economic crisis, in particular after 2007. It is noteworthy, that the tourism sector in Aruba gained in strength during that time, but without a rise in local purchasing power (we do recollect the closing of the Oil Refinery).

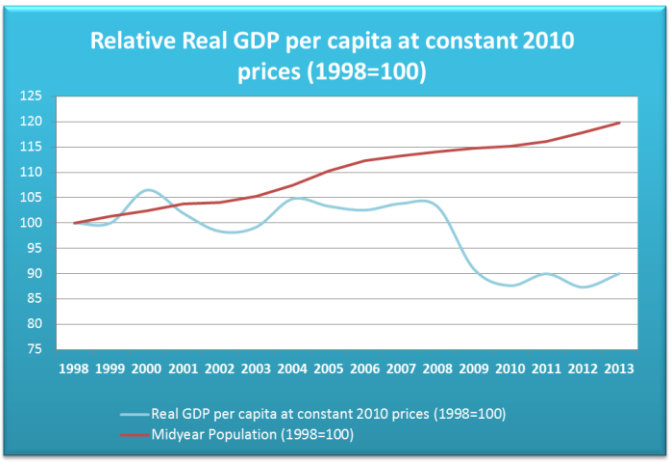


Figure 2 Development of the real GDP per capita and the midyear population in Aruba relative to base year 1998.
Source: Centrale Bank Aruba; CBS Aruba.
Note[7]: Index 1998 = 100%

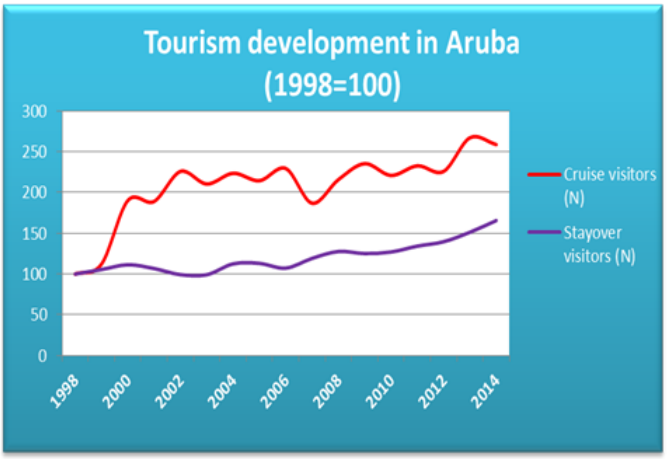


Figure 3 Development of the number of tourist visitors in Aruba in recent decades relative to base year 1998.
Source: CBS Aruba. Note: Index 1998 = 100%

Suburban sprawl and rising housing costs

The growing economy and increase in population numbers required land for the construction of houses and economic facilities. Land owners made value from this demand and readily parceled their formerly cultivated, but now wildered property lands (Ridderstaat, 2007). Large pieces of land were parceled and turned into smaller residential areas. The plots along the main roads and near the economic centers primarily deserved major interest. Thus, the countryside turned into a ribbon-like appearance of spatial developments. The transition from dispersed Cunucu houses into a ribbon-shaped spread of development along the roads is a typical first step in the process of suburbanization. This and the next phase can still be discerned on the map in figure 9.

[5] When all products are bought and sold, total **production** should in principle equal total expenditures for consumption. The GDP can thus be calculated and represented accordingly by the consumer expenditures (all expenditure that is made through purchases) plus the investments (additional expenditure that is invested) plus the government spending, corrected for the value of exports (as these products are produced but not bought within the country) minus the value of imports (as these goods are consumed but were part of a production elsewhere)

$$GDP = Exp_C + Inv + Exp_G - Export + Import$$

Thus, the gross domestic product (GDP) includes only the goods and services produced or consumed within the geographic boundaries. If depreciation of the national capital stock is deducted from the GDP, it is called the net domestic product (NDP). If the net income from activities (production) abroad is added, it is called the gross national product (GNP). The GDP per capita is frequently used as a measure of the consumers' well-being or standard of living. The measure however requires careful interpretation when it is used to compare between countries, since it does not take into account the distribution of incomes (and these are likely to be more skewed in low income countries) nor does it take into consideration what one can get in the country for the money earned (the same products can be relatively cheap or much more expensive in one country compared to the other).

[6] Standardization of the common consumption basket between two countries is attained by using the purchasing power parity index (PPP) of a countries' currency relative to that of the other country. The correction that is used to calculate the Real GDP thus differs from the common PPP standardization.

[7] Index 1998 = 100% which means we have translated down the original graph from its position with real GDP per capita in 1998 at 114% towards 100%. The shape of the graph remains the same

The map shows the spatial extent of subsequent periods in construction. Pockets of land were originally left open behind the roads, but soon became parceled and turned into residential neighborhoods and sometimes with an enclosed network of roads (see figure 14). This is the final step in suburbanization, i.e. when the few still remaining wild pockets of land aside the build-up areas are converted as well into areas with a socio-economic purpose. This trend appears to exist in all parts of the island with the exception of the more inaccessible parts along dry-river beds and along the Northeast coast, outside the National Park (see Figure 9).
These changes are slow and may remain virtually unnoticed. With the advancement of construction, also into the more far-out regions, more and more wild or wildered spaces are about to become defragmented.

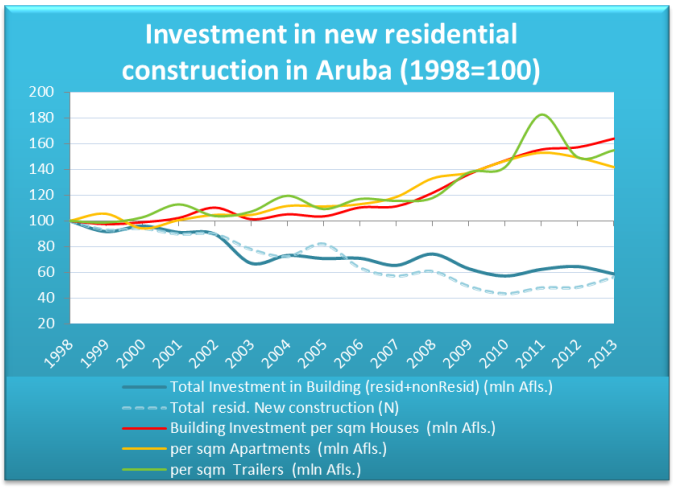


Figure 4 Frequency and investment in new construction in Aruba, relative to base year 1998,
Source: CBS Aruba.
Note: Index 1998 = 100%

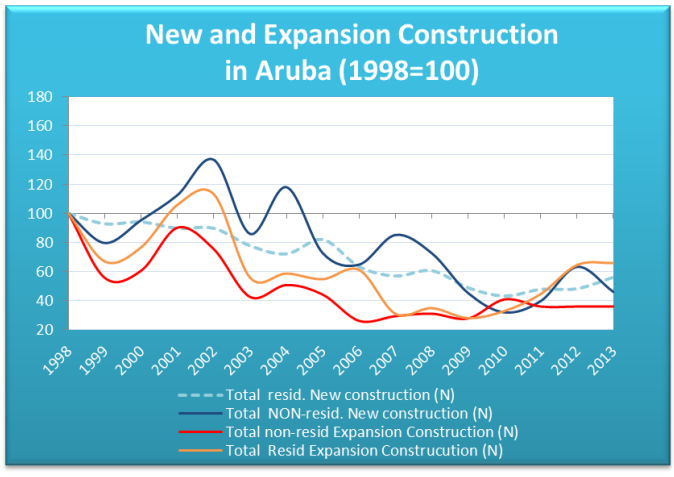


Figure 5 Frequency of new and expansion constructions during the period 1998 – 2010
Source: CBS Aruba.
Note: Index 1998 = 100%

In 1998 the peak in building applications had already passed. As of 1998 the total investment in buildings continues to drop at an almost steady rate (Figure 4). The investment per square meter of living area (for houses, trailers, and apartments) tended to increase in a similar almost steady pace until 2011 when the square meter (sqm) investment in trailers attracted incidentally and investment in apartments tended to drop. The reason for the risen interest in investment in trailers is unknown. The sqm investment in houses continues to rise. The higher investments per square meter contrasts to the lower total investment. It is apparent that the total number of new (residential) buildings is dropping, be it that in 2013 there seems to be a slight growth.
The drop in investment is not only in new construction, but also in expansion construction, residential as well as non-residential (Figure 5). The overall trend during the last decennium is downwards for 'new' and 'expansion' construction, although as of 2010, this trend seems to reverse after years of investment alternated with years of retainment. We are certain that there is much more to say about why these numbers go up and down, but in the context of this paper it suffices to reveal that there is a slowing down of construction up to 2010, but with an apparent change and increase during the years thereafter.

Nonetheless, it is important to realize that although relative to 1998 new construction is slowing down; there is still a continuing net increase in total number of constructions in Aruba.
This trend is represented in more detail in figure 6. The decrease in new construction reverses in 2010, but predominantly for residential apartments, while the yearly increase in new houses remains nearly constant.

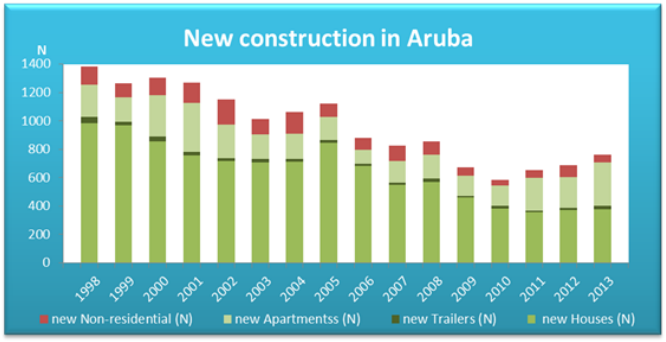


Figure 6 New constructions during the period 1998 – 2010
Source: data from DOW Aruba in Statistical Yearbook, CBS Aruba.
Note: Index 1998 = 100%

Next, we describe the situation at the beginning of the last century on the basis of the Werbata-Jonckheer map. The extent of agriculture cannot be understood without knowledge of the geological substrate (Figure 7). So, first we analyze the occurrence and extent of exploitation of the landscape at around 1911, and then we describe in detail the trends in housing developments over the last hundred years (Figure 8) with the use of GIS technology[8].

[8] A GIS (Geographic Information System) is a computer-based tool that enables the linking of information from many different fields on the basis of a common geographic component. Layers with information from for instance, socio-economic, environmental and topographic surveys can be brought together and analyzed on a common spatial scale. Linked in this manner, the GIS system provides additional information and opportunities for research.

Information derived from historic maps

Several geological maps exist in Aruba, with the focus on different geological epochs and different types of geological substrate. A number of these maps have been digitized and translated into a series of GIS[9] information layers that made a comparison of relevant spatial information possible.

The geological map of J.H. Westermann (1932) provides an initial synopsis of the geology of the island. The later map of P.H. de Busonjé (1960) and the more recent map from the 'Rijks Geologische Dienst' (Beets, 1996) provide, among other features, detailed information about the type of rock substrate of the Batholith, the Limestone Terraces and the Aruba Lava Formation[10]. We have chosen to represent information from the two more recent maps, the map from de Busonjé and the map from Beets, in conjunction with other type of local spatial information.

Information about the type and extent of agricultural land-use at its moment of climax is derived from the period 1909-1911 from the Werbata-Jonckheer map (Werbata, 1913) and is shown in overlay with the maps from Busonjé and from Beets (respectively Figure 7a and Figure 7c). Information about the height topology is also shown as background information in Figure 7b. Next, we compared the coincidence of geological substrate with the type and extent of agricultural land-use in 1911.
The information from the Werbata-Jonckheer map is used to compare the extent of industrial, housing and agricultural developments between early 20th century and early 21th century as wel (figure 8 and 9). After scanning and geo-referencing the geological and historical topographic maps, we extracted the extent of relevant features with the use of GIS Geographical Information System technology (ArcGIS v9.3.1, ESRI) and stored the information in a geodatabase for further spatial analyses.

The landscape in early 20th century

The Werbata-Jonckheer map is the first detailed topological map of Aruba (Krogt, 2006) and reveals valuable information about features in the landscape of a hundred years ago. Within the scope of our current interest we visualized the location and extent of the relevant features that can be discerned on the Werbata-Jonckheer map in Figure 8.

Infrastructure

In 1911, the total road infrastructure was about 131 km, and included 79 km of road (Dutch: rijweg)[11] and 52 km of cart-track (Dutch: karreweg). A total length of 288 km footpath's connected all parts of the island.

Mining

In 1879, Phosphate Limestone deposits (fossilized Guano) were first mined in Sero Colorado at the southern tip of Aruba. Phosphate exploitation was very lucrative up to WWI. A tramline ran from the Phosphate mine in Seroe Colorado to the port of San Nicolas where the phosphate was shipped to abroad.
A total of 19 separate locations on the map indicate that there was some level of gold digging at the time. The locations were situated more to the east, central and in the north, and understandably on quartz-diorite grounds.

Agriculture

Figure 7 shows the location of the enclosed grounds that are marked on the Werbata-Jonckheer map and characterized as cacti or stone-fenced agricultural terrains or more specific terrains for Aloe production. Small icons on the original map pinpoint typical natural resources, such as scattered fruit trees, but the delineation of such areas is not always obvious. The Werbata-Jonckheer map also reveals the location of a number of orchards, but without information about the kind of trees. So, aside of the description of enclosed Aloe terrains, the map doesn't provide specific spatial information about other products, such as corn, beans or any other vegetable or fruit that were common in early 20th century. Neither does the map reveal information about where farm animals or free-roaming goats, sheep or pigs may be typical. Nevertheless, the map is still very informative.
For instance, the map does provide information about the road infrastructure in 1911, the water distribution system, the location of mines, wells (wind milled and otherwise), tanki's, salt pans, houses and construction material, etc.
Such information can be relevant to understand the scope and magnitude of agricultural exploitation and economic activity a century ago in comparison with today.

Windmills

It is interesting to note that at the time, in 1911, there were quite a number of wind-milled wells, in particular at a distance parallel to the northwest coastline, just east of present day Bubali Plas. Driven by the windmills of a well called '*Pos Sjon Jan',* water was transported via wells in 'Madiki' in a pipeline system to a freshwater reservoir in Rancho; one of the neighborhoods in Oranjestad. A similar pipe system existed at the Southern tip of the island, between San Nicolas and the freshwater wells in Mangel Cora, in Sero Colorado, next to Klein Lagoen (today called 'Baby Beach'). There, a few wind-milled wells drew freshwater from a large natural freshwater aquifer. The majority of wells, however, were located in the northwest.

Plantations

The Werbata-Jonckheer map also shows the location of 23 mostly small plantations with mixed agriculture, coconut trees and housings. They were generally located near the larger dry-river beddings on the 'Lower Terrace' deposit fields in the northwest, near the Frenchman Pass, in 'Dos Playa' and 'Andicuri' at the northeast coast. A single larger plantation was situated more inland, north of Oranjestad in 'San Barbola'. The 'township' Savaneta actually origins from a governmental plantation that later turned into a small village (Alofs & Romondt, 1997).

[9] GIS technology offers the tools to integrate and compare detailed social and economic information with environmental and landscape, soil or geological information, as long as a common spatial component is available.

[10] For a better understanding of the differences between Aruba Lava Formation, Batholith and Limestone Terraces, etc., we refer to an earlier publication in this series on the landscape (Derix, 2016c)

[11] The total length of road infrastructure today is about 1,000 km

Saltpans

At some locations along the Southwestern coastline, at near sea-level on the coral/beach rock ramparts, and, in some of the salinas, located, in 1911, a total of 6 saltpan production plants:

1. Bubali Plas
2. Punta Brabo
3. Oranjestad
4. Kas Paloma
5. Savaneta
6. San Nicolas

Salt was a desired resource and shipped to abroad, but was also used locally.

The relation between geological substrate and early land-use in 1911

First, we calculated the coverage of the enclosed grounds that were mapped in 1911 as Aloe cultivation and as cacti and stone fenced agricultural land on the main geological formations (Table 1).

At the turn into the 20th century, Aloe cultivation was probably about at its height of production. The total area covered with Aloe cultivation in 1911 is calculated to be about 20.9 km^2, which covers about 11.7% of the Aruban surface area (Figures 7 and Table 1). The total area in 1911 that was covered with cacti- or stone-fenced agricultural terrains, aside from the Aloe fields, is about 37.9 km^2 and covers about 21.1% of Aruba's surface area. Thus, in total, at least 32.8% of Aruban soil was in use for agriculture.

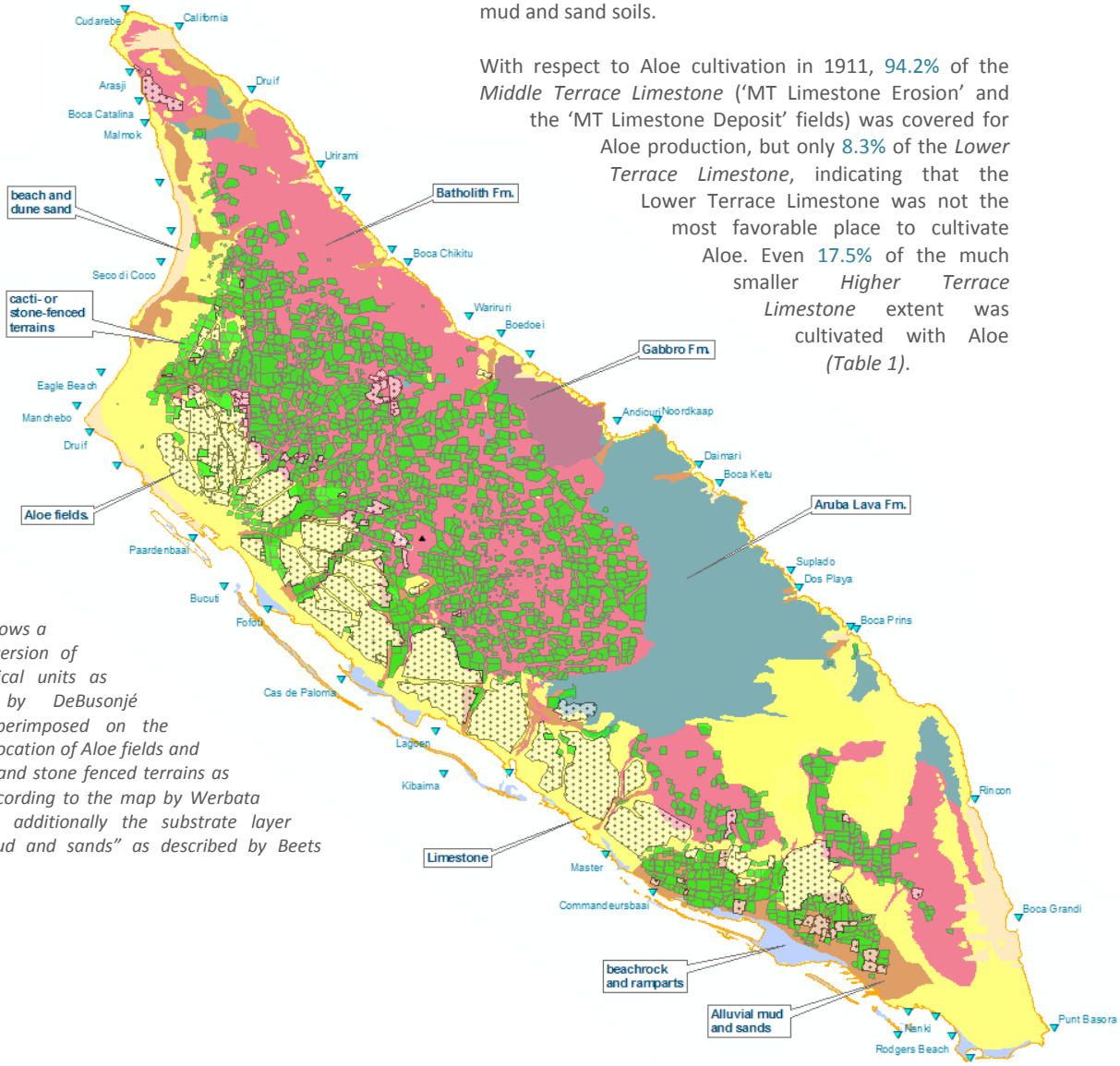


Figure 7.
The map shows a simplified version of the geological units as described by DeBusonjé (1960). Superimposed on the map is the location of Aloe fields and other cacti and stone fenced terrains as in 1911, according to the map by Werbata (1913) and additionally the substrate layer "alluvial mud and sands" as described by Beets (1996).

A detailed account of the spatial extent of agriculture today is not available, but local farming is not as widespread as it was in early 20th century, based on the information from the Werbata map. Agricultural activities today confine to only a limited number of terrains.

The extent of Aloe cultivation in 1911

It is interesting to mention the sharp demarcation of Aloe fields that concurs with the delineation of limestone terraces in the southwestern coastal areas (Figures 7). The spatial concurrence of Aloe fields on the Pleistocene Limestone Terraces all along the western coast is strong and represents 88.1% of all Aloe cultivation in 1911, in contrast to 10.8% on the Batholith (Table 1 and Figure 8).

The map by Beets (Beets, Metten, & Hoogendoorn, 1996) reveals the location of alluvial muds and sands from the dry-river beddings that have cut through the Limestone Terraces and that cover part of the southwest near the coast. We have shown in figure 7 the exact location of these erosion fields that find their origin in recent Holocene, a relatively young geological time period (approx. 11.000 yrs. - today). Interestingly, the Werbata-Jonckheer map reveals that there was quite some Aloe production on these erosion fields in 1911 (7.5% of all Aloe cultivation covers about 10% of alluvial mud and sands soils), albeit that the use for agricultural exploitation other than Aloe cultivation was most typical on the alluvial mud and sand soils.

With respect to Aloe cultivation in 1911, 94.2% of the *Middle Terrace Limestone* ('MT Limestone Erosion' and the 'MT Limestone Deposit' fields) was covered for Aloe production, but only 8.3% of the *Lower Terrace Limestone*, indicating that the Lower Terrace Limestone was not the most favorable place to cultivate Aloe. Even 17.5% of the much smaller *Higher Terrace Limestone* extent was cultivated with Aloe *(Table 1)*.

Total Geological Substrate cf. Busonje Map 1960 including rif islands			Aloe fields			Cacti-and stone fenced Agricultural land		
GEO Layer	total area (sq km)	% Total	total area (sq km)	% Total	% GEO layer covered by Aloe	total area (sq km)	% Total	% GEO layer covered by Agric.
ALF	23.7	*13.2*	0.2		*0.9*	0.3		*1.2*
Aruba Lava Formation Fm	**23.7**	***13.2***	**0.2**	***1.0***	*0.9*	**0.3**	***0.7***	*1.2*
QuartzDiorite	76.9	*42.9*	2.2		*2.9*	30.6		*39.8*
PhosphoLimestone	0.1	*0.1*	-		-	-		-
Limestone Eolianite	7.1	*4.0*	-		-	0.0		*0.6*
Hooibergite	0.6	*0.3*	0.0		*0.8*	0.1		*11.8*
Granite	0.1	*0.0*	0.0		*36.2*	0.0		*24.0*
Gabbro	3.4	*1.9*	-		-	0.1		*27.0*
Batholith Fm	**88.2**	***49.2***	**2.3**	***10.8***	*2.6*	**30.8**	***81.4***	*35.0*
MT	38.2	*21.3*	17.0		*94.2*	6.2		*25.0*
HT	3.1	*1.7*	0.1		*17.5*	0.0		*2.5*
LT	16.6	*9.2*	1.4		*8.3*	0.4		*2.3*
Limestone Terrace Fm.	**57.8**	***32.3***	**18.5**	***88.1***	*31.9*	**6.6**	***17.5***	*11.5*
CalcSand_Dune	4.5	*2.5*	-		-	0.1		*1.2*
(sub)recent Coral Shingle/ Bea	3.6	*2.0*	0.0		*0.1*	0.0		*0.4*
Salinas-Rainwater	1.6	*0.9*	0.0		*0.4*	0.1		*3.4*
Coastal Region	**9.7**	**5.4**	**0.0**	***0.0***	*0.1*	**0.1**	***0.3***	*1.3*
	179.3	***100***	**20.9**	***100***	***11.7***	**37.9**	***100***	***21.1***

Table 1 The listing shows subsequent geological units in Aruba and their respective surface areas as well as the amount of coverage by Aloe fields and cacti or stone fenced agricultural land in 1911. Source: Geological map from DeBusonjé (1960).

Only about 0.9% of the Aruba Lava Formation was covered with Aloe cultivation. This corresponds to about 1% of all Aloe cultivation at the time. There is also little Aloe cultivation on the Batholith and this is only limited to a few locations. One is in a single spot near Jaburibari (see Figure 7) and another concerns some scattered plots west of the Hooiberg (Meiveld, Primavera and Seroe Biento). The geological information from the maps by Westermann (1932) and De Busonjé (1974) shows that in the latter region Aloe cultivation coincided with the presence of small patches of *granite* substrate (36.2% of this granite substrate was covered with Aloe). From the Soil Potentiality Map (Grontmy De Bilt; Sogreah Grenable, 1967) we learn that the specific area in Jaburibari coincided with shallow sandy soils, but that otherwise, the area was geologically, and in soil composition not different from its surroundings. So, information from geology or soil potentiality alone is insufficient to help explain why there was a concentration of Aloe exploitation in these areas on the batholith, specifically. Otherwise, the combination of older maps (topological, geological or soil maps) proved to be a strong methodology to be able to recognize patterns in the land use that concur with patterns in spatial information; in this case, information about the geological substrate.

The extent of agriculture in 1911

In 1911, 81.4% of all the cacti or stone fenced terrains that were used for agricultural exploitation other than for Aloe cultivation were on the *Aruba Batholith,* and they covered *39.8% of all the Quartz Diorite* substrate (Table 1 and Figure 8). *Similar agriculture terrains cover* respectively *27%* of *the Gabbro* substrate and *24% of* the dispersed pockets of substrate with *Granite* rock. But, also *17.4%* of this agricultural extent was situated on *Limestone* substrate of which the majority was situated on the Middle Terrace Limestone Deposits (Derix, 2016c).

This specific area covers predominantly the region of current-day Savaneta in the southwest (Figure 7). As mentioned previously, in the region Savaneta the soil substrate is different as it contains on top of the Limestone Terrace much alluvial mud and sands (Beets, Metten, & Hoogendoorn, 1996). The area with alluvial mud and sands coincides almost completely with the spatial extent of agricultural exploitation in this region in 1911.

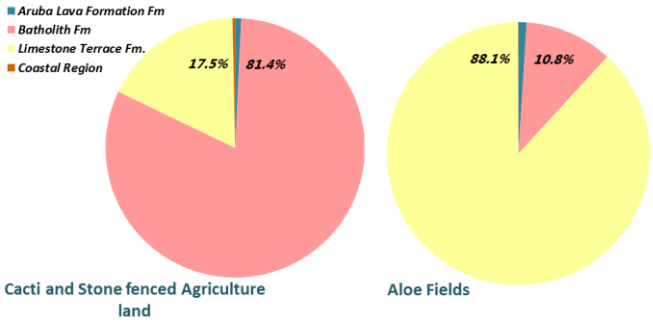


Figure 8 The proportion of total Aloe cultivation and of total agricultural land-use that was situated on each of the main geological formations, Aruba Lava Formation, Batholith Formation and Limestone Terraces, according to Busonjé (1960).

A similar association was observed in the other regions with erosion and sediment streambeds where dry-rivers had cut through the Limestone terraces (Figure 7). Alluvial sediments contain a high percentage of the hinterland rock substrate, in this case from a Quartz-Diorite/Tonalite hinterland (Sambeek, Eggenkamp, & Vissers, 2000).

Not indicated in Table 1, but it is interesting to note that 41.1% of all the area with the alluvial mud and sands that cut through the Limestone Terraces, were covered with cacti and stone fenced terrains (indicative for agricultural exploitation) against only 10.2% of the areas was covered with the Aloe fields (Figure 7).

Housing in 1911 and 2010

Housing at the beginning of the 20th century was scattered and spread all across the agricultural countryside, with the exception of Oranjestad and to some degree also Savaneta. There was a dominance of agricultural development other than Aloe cultivation in the central regions where farmers typically live next to their land.

We refer to the information from the Werbata-Jonckheer map that we digitized and translated into GIS layers and that we present in figure 9. Houses were typically absent near the northeast coast and in the hills of todays' National Park Arikok. Obviously, agricultural development was cumbersome in these areas. Inhabitation was absent as well in the lower-lying areas along the west coast where there were still large rainwater plains and along the northeast coast where salt spray was intense.

The vast Aloe fields were situated in the southwest on the Limestone Terraces, at a short distance from the coast, up to 2-3 km inland. Typically, the large Aloe fields were thinly inhabited. Exceptions exist on the alluvial soils where the dry-rivers cut the Limestone and in the south, along the stretch between Savaneta and Brasil up to San Nicolas. As suggested in a previous paper (Derix, 2016c), these areas may have different, more fertile, alluvial soils.

At the time, in 1911, houses were made from twigs and clay and from stone. Interestingly, most houses in the center of Oranjestad were (still) made from wood. Oranjestad also had the largest concentration of stone houses. Similar concentrations of stone houses can be observed in Savaneta, at the Balashi Gold factory and at the Phosphor-limestone mine in Culebra near Seroe Colorado (Figure 9). Some of these houses were built from bricks that had been imported from Amsterdam, whereas the houses that were built more inland commonly were built from locally available rocks and stones (Bakker & Klooster, 2007).

In the map of figure 9 we show the location of each of the individual constructions. The colored dots represent the types of construction material that were most common in 1911, i.e. stone-built, from clay, twigs and mud, or from wood. Quite a large concentration of man-made water wells were situated at some distance from the west coast, many of which were *wind-milled.* It is evident that all over the island there have been huge changes in the spread of housing over the last century, between 1911 and 2010 (compare figure 9 with figure 10). For the sake of comparison, we superimposed on the map in figure 9 the location of main economic activity in 2010.

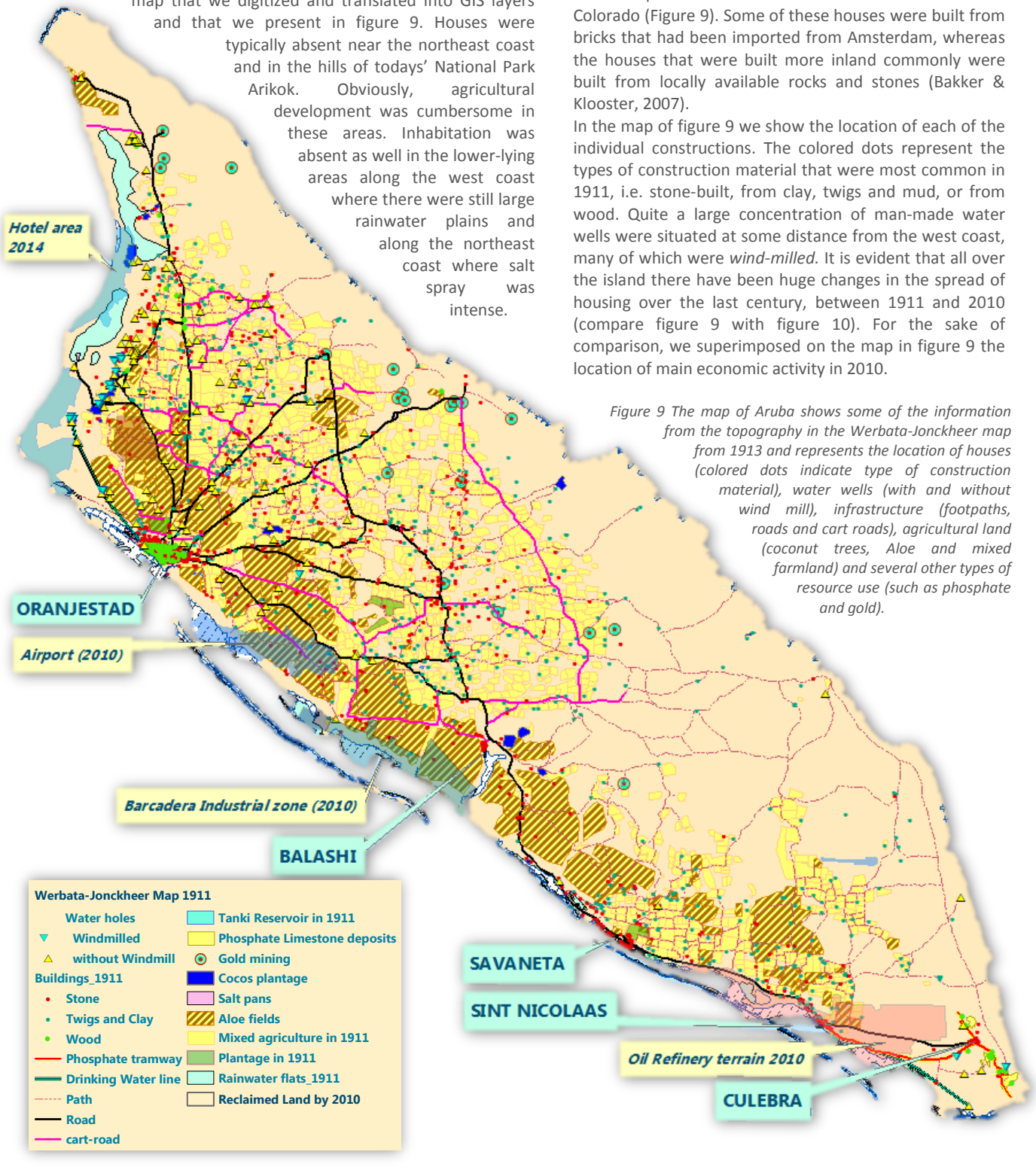
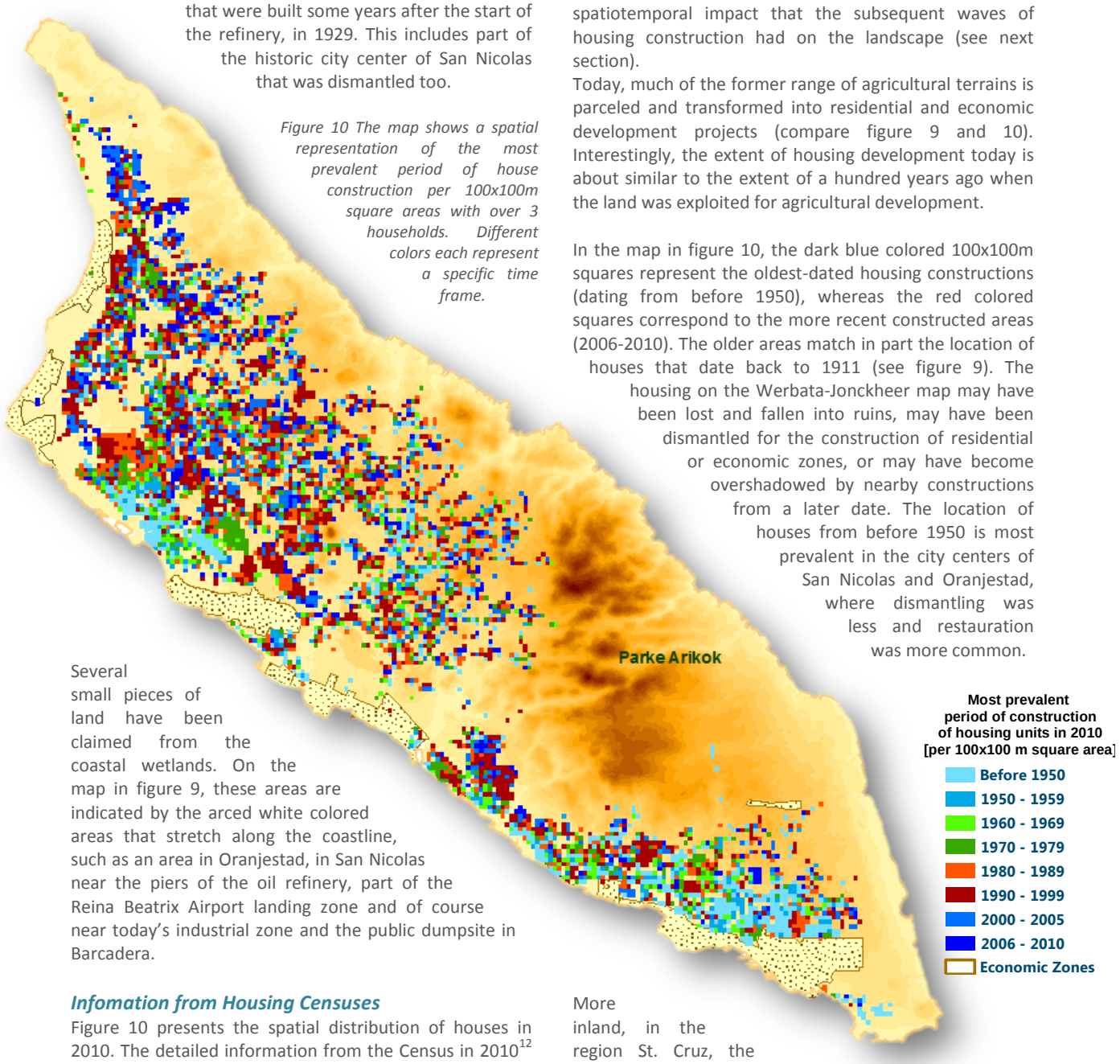


Figure 9 The map of Aruba shows some of the information from the topography in the Werbata-Jonckheer map from 1913 and represents the location of houses (colored dots indicate type of construction material), water wells (with and without wind mill), infrastructure (footpaths, roads and cart roads), agricultural land (coconut trees, Aloe and mixed farmland) and several other types of resource use (such as phosphate and gold).

Today, the wooden houses in Oranjestad have long been replaced by modern commercial centers. In San Nicolas, most of the wooden houses have been gone as well. The use of GIS enables to review the extent of construction from different time periods, superimposed on top of each other. Figure 10 reveals that some of the houses disappeared behind the walls of the oil refinery that were built some years after the start of the refinery, in 1929. This includes part of the historic city center of San Nicolas that was dismantled too.

Figure 10 The map shows a spatial representation of the most prevalent period of house construction per 100x100m square areas with over 3 households. Different colors each represent a specific time frame.



Several small pieces of land have been claimed from the coastal wetlands. On the map in figure 9, these areas are indicated by the arced white colored areas that stretch along the coastline, such as an area in Oranjestad, in San Nicolas near the piers of the oil refinery, part of the Reina Beatrix Airport landing zone and of course near today's industrial zone and the public dumpsite in Barcadera.

Infomation from Housing Censuses

Figure 10 presents the spatial distribution of houses in 2010. The detailed information from the Census in 2010[12] (CBS Aruba, 2010) made it possible not only to distinguish the time of construction categorized in subsequent decades, but also to present this information at a spatial resolution of 100x100 meter square areas. The colored squared areas in figure 10 vary from blue, over to yellow, and red, and reveal the differences in 'most prevalent period of construction'[13] of the houses that fall within each of the 100x100m inhabited areas. Such fine level of spatial resolution is more informative than would be possible based on a representation by GAC zones (GAC, 2012). This is useful to better understand the actual spatiotemporal impact that the subsequent waves of housing construction had on the landscape (see next section).

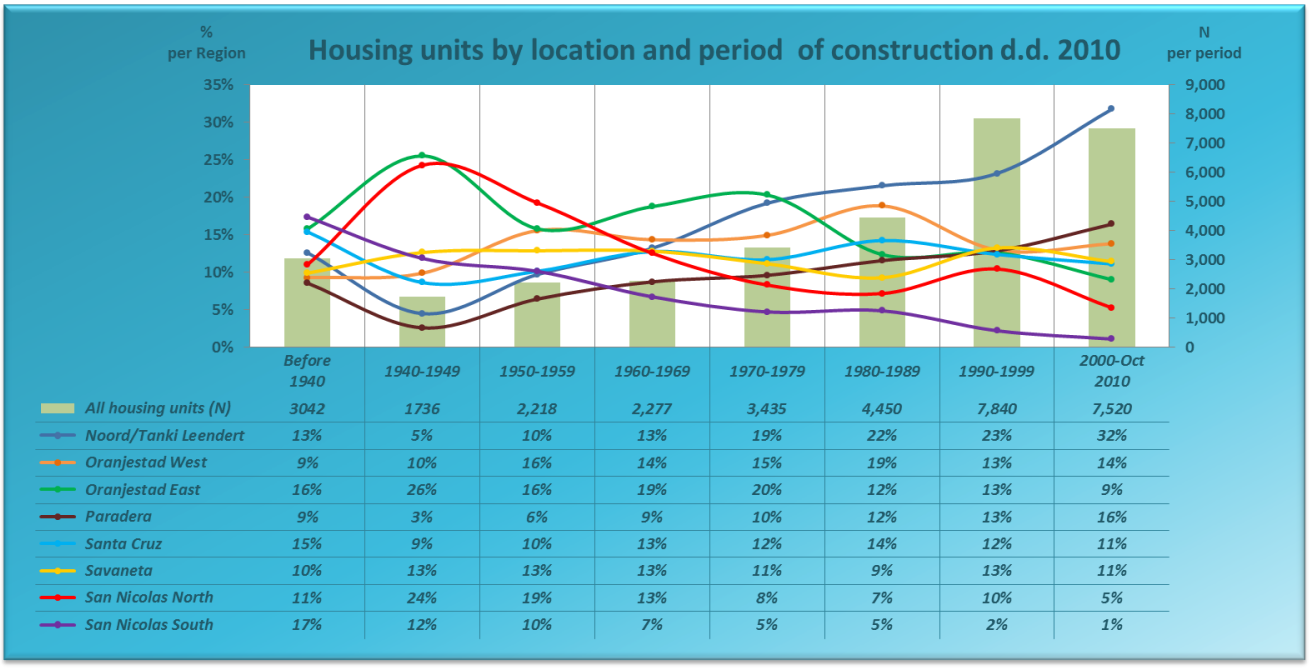
Today, much of the former range of agricultural terrains is parceled and transformed into residential and economic development projects (compare figure 9 and 10). Interestingly, the extent of housing development today is about similar to the extent of a hundred years ago when the land was exploited for agricultural development.

In the map in figure 10, the dark blue colored 100x100m squares represent the oldest-dated housing constructions (dating from before 1950), whereas the red colored squares correspond to the more recent constructed areas (2006-2010). The older areas match in part the location of houses that date back to 1911 (see figure 9). The housing on the Werbata-Jonckheer map may have been lost and fallen into ruins, may have been dismantled for the construction of residential or economic zones, or may have become overshadowed by nearby constructions from a later date. The location of houses from before 1950 is most prevalent in the city centers of San Nicolas and Oranjestad, where dismantling was less and restauration was more common.

More inland, in the region St. Cruz, the ribbon-like occurrence of houses from before 1950 is relatively common and still visible.

[12] During the Census in 2010, 7% of respondents did not provide information about the age of construction of the housing unit. The lowest percentage of 'not reported' was present in the larger region of Savaneta (3%) and the highest in the region of Oranjestad (10%). In Oranjestad many housing units are rented and quite old. Thus, inhabitants may have been unfamiliar with the precise date of origin of their living quarter.

[13] Houses that were constructed before 1950 are obviously over-represented since this category spans more than a single decade. On the other hand, the older the houses the more likely they have turned into a ruin or were demolished, even though nowadays there is a trend to restore and expand old houses. Likewise, an over-representation is present for the recent decade as this period includes an additional nine months, from January 2000 until the day of the Census, September 29, 2010.



	Before 1940	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-Oct 2010
All housing units (N)	3042	1736	2,218	2,277	3,435	4,450	7,840	7,520
Noord/Tanki Leendert	13%	5%	10%	13%	19%	22%	23%	32%
Oranjestad West	9%	10%	16%	14%	15%	19%	13%	14%
Oranjestad East	16%	26%	16%	19%	20%	12%	13%	9%
Paradera	9%	3%	6%	9%	10%	12%	13%	16%
Santa Cruz	15%	9%	10%	13%	12%	14%	12%	11%
Savaneta	10%	13%	13%	13%	11%	9%	13%	11%
San Nicolas North	11%	24%	19%	13%	8%	7%	10%	5%
San Nicolas South	17%	12%	10%	7%	5%	5%	2%	1%

Figure 11 Distribution of Aruban housing units per region and period of construction.
Note: Collective living quarters have been excluded from the analysis.
Source: Census 1991 and Census 2010, CBS Aruba

Not easily visible in the representation in figure 10 is the shift over subsequent periods of time in the location of economic and residential hotspots from San Nicolas northwards to Oranjestad and to the hotel area in Noord. We will discuss this transition next and refer to the representations in figure 11 and 12.

Quite revealing is the interplay of up and down going trends in house constructions per region[14]. The underlying information in figure 11 is from consecutive censuses in 1991 and 2010 and is based on the date of construction of the housing at the time of the Census. Old houses will certainly have been lost over time, possibly blurring the picture shown above. However, we may assume that the number of possibly lost houses will have remained low as housing stayed in high demand and there is a trend to renovate old cunucu houses and even ruins, as opposed to tearing these houses down.

The pattern in figure 11 is best described as a *wave of construction* across the island, based on a shift in local or regional interest in economic development or at least a shift in the interest for the new housing opportunities that each of these regions characterized during subsequent time spans.

Figure 11 shows that across all regions in Aruba, a near equal percentage of houses exist that date back to the period from before 1940 (range between 9-17%).

Of the houses that originate from the period 1940-1949[15] (during and after WWII), a disproportional large part, respectively 26% and 24% are located in the region '*Oranjestad East*' and '*San Nicolas North*'. These neighborhoods are the earliest indication of a wave of construction that first started to house the workers in the oil refinery at the time of WWII, which shifted northwards to house the workers in the tourism industry and the facilitation industry.

From all houses today, proportionally, the majority from the time 'before 1940', are still situated in *San Nicolas South* (17%) and in *Oranjestad East* (16%). From the houses that are built more recently, between 2000 and 2010, the majority are situated in the larger region *Noord/Tanki Leendert* (32%).

At the finer scale, this shift is detectable in the more complex figure 10 as well, when we focus on the dark blue and red colored 100x110m square areas only.

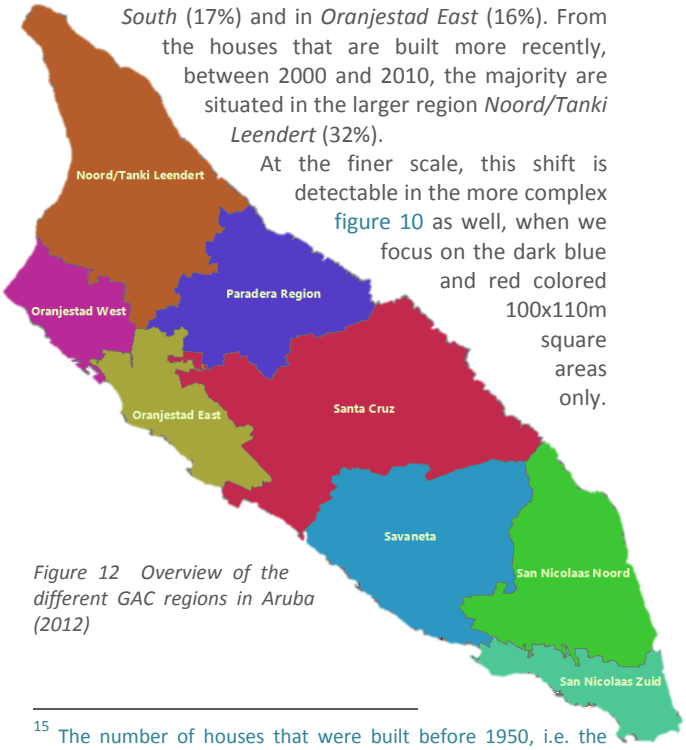


Figure 12 Overview of the different GAC regions in Aruba (2012)

[14] For each of the regions separately we presented the frequency of new construction across the subsequent time frames as a line to ease readability and emphasize the shift in region-specific interest for new construction.

[15] The number of houses that were built before 1950, i.e. the categories 'before 1940' and '1940-1949', were based on a combination of information from the Census in 1991 and 2010. The information from the Census in 1991 was only available at the level of GAC zones and regions, thus limiting the spatial resolution of the information that we show in figure 11.

In the 40s, economic interests shifted away from *San Nicolas South* towards predominantly *San Nicolas North* and *Oranjestad East*. The disproportional interest for new construction, however, dropped after WWII. Not only in *San Nicolas South,* where new construction already dropped from the '40s onwards, but more strongly so in *San Nicolas North* and in *Oranjestad East* that lost both their prominence during the '50s (follow respectively the purple, green and red lines in figure 11).

Figure 11 reveals that, proportionally, during the 60s and 70s new house construction was highest in the region *Oranjestad East* with respectively 19% and 20%. After the 50s house construction also increased in *Oranjestad West* (from a proportional 16% in the 50s compared to other regions up to 19% in the 80s, which was when *Oranjestad West* became the most desired location for new construction. Aside from this peak during the 80s, throughout the subsequent decennia the activity in house construction in the *Oranjestad West,* however, remained proportional at a quite steady level similar to the situation in the regions *Savaneta* and *Santa Cruz*.

The pattern of house construction in *Noord/Tanki Leendert* and *Paradera* is different. While during the 40s the regions *Noord/Tanki Leendert and Paradera* received the least interest for growth in new construction, over time, the relative attractiveness for new residential housing steadily increased to become the regions where proportionally most new construction took place.

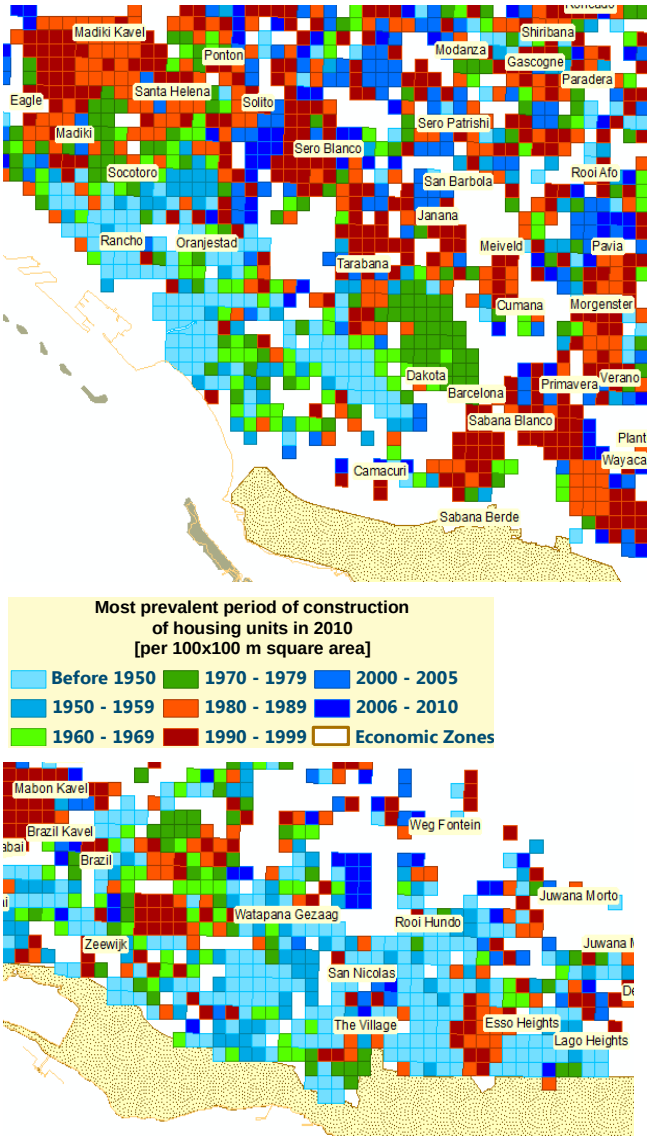
Summarizing, the regions *San Nicolas South, Oranjestad East* and *San Nicolas North* followed each other in prominence for new housing construction during the periods 'before 1940, the 40s and the 50s, whereas thereafter, during the 60s and the 70s this role remained for *Oranjestad East* consecutively, and from then onwards (80s, 90s and up to 2010) the region *Noord/Tanki Leendert* appeared pre-eminently most attractive.

There is another aspect of the island wide spread of housing construction that deserves mentioning. In the surroundings of Oranjestad (Figure 13a) and San Nicolas (Figure 13b) we recognize larger areas with predominantly similarly aged houses (Madiki, Rancho and Dakota and The Village and Esso Heights). These areas correspond to neighborhoods and former governmental housing projects that were constructed in a relatively short period of time to provide affordable housing for the workers[16] in the hotel and the oil industry, respectively.

Also, we can observe small neighborhoods with similar aged houses. These correspond to known small housing projects by foreign investors or by local land owners who, under own proprietary rule, parceled their land to sell the individual plots separately. Over the last decade, similar aged housing projects were built, but now they are found most frequently in the regions *Noord/Tanki Leendert* and *Paradera*.

[16] One of the two oil refineries at the time, the Arend Oil refinery (1928-1953), situates just north of Oranjestad, at the most western tip of the island. The other oil refinery situates in San Nicolas, in the South, and changed between its opening in 1928 and its last closure in 2012 several times from ownership.

Figure 13a (top) and Figure 13b (below) Distribution of Aruban housing units at the time of the Census in 2010 per most prevalent period of construction in Oranjestad (figure above) and San Nicolas (figure below).



In general, aside from the smaller and larger (non-) governmental development projects, there is considerable spatial spread in the time of new construction all across the island (see also figure 10).

As mentioned before, tourism and the accompanying facilitation industry are still booming and attract a range of recreation- and food-establishments at the strip near the high-rise hotels. These not only attract tourists, but local inhabitants as well. In a relatively short time span the area of Noord became the booming center of economic and recreational activities. Noord is currently considered to be the point of attraction for foreign investment projects. In contrast to local private housing projects, which are situated more inland, the larger projects in Noord have a focus on well-to-do foreigners. Many of the predominantly low-salary local workers in the tourism sector, however, live in Oranjestad or even come as far as from San Nicolas and cannot afford the high prices for new housing in the nearby region '*Noord'*.

Consequently, they commute on a daily basis over the relatively large distance between San Nicolas and the Hotel strip in 'Noord'. Figure 13 presents per 200x200m inhabited area, the most prevalent distances that employees cover to their work on a regular basis (Derix, Traffic between school, work and home in Aruba in 2010, 2013b). We will discuss the changes in infrastructure in more detail, next.

Impact from the shift in housing on the landscape

It is likely, that now, as residential construction has spread across most of the island, San Nicolas and surrounding areas may become once again attractive for housing expansion. After the closure of the oil refinery in 2012, the region lagged behind in economic progress, but there is still much inhabitable space available and plans exist to revitalize the economy in this part of Aruba with a restart of the oil refinery. If this materializes, it is likely that this will have consequences for the local landscape and natural habitats. A project to ease current traffic flow (Aruba, 2013) between San Nicolas and Oranjestad is already in development.

Consequently, in just over half a century, little by little, the wildered land or 'Mondi' disappeared in most regions as it turned into new development projects. Accordingly, the face of the former (wildered) agricultural landscape or cunucu transformed into its current suburban state.

As an illustration of the pressures on the natural space, we give a photo (below) that shows the eagerness of two local birds (Burrowing Owl) to find a suitable nesting site in the drastically changing landscape.

Photo: The arrows show two Burrowing owls () next to their new burrow in a temporary heap of shoveled earth in an area where the land was cleared for new housing development. The animals appear to be quite adaptable in finding a site as their old habitat withdraws in fast pace, but it is unlikely that they will be succesful as this heap of sand is only temporary and antropogenic disturbances will continue. (Photo: Ruud Derix, 2003)

It is notable that construction continues even in areas that formerly were undesirable for building, for instance close to the northeast coast under the pressures of the salt laden winds that easily corrode building materials, or, in the more central regions in Aruba amidst the heaps of large dioritic boulder formations. Destruction and removal of some of these rock formations is of consequence (Barendsen, et al., 2008).

The stretches along the Northeast and Southeast coastline form a few of the yet relatively 'untouched' habitats that are still left in Aruba and that play a role to serve local recreation and tourism. The stretch along the Northeast coastline is conveniently named already the future *'Salt Spray Park'* (DIP, 2009).

There is still some network of small wildered patches in the island interior, within inhabited areas, that are thought to play an important role as habitat corridors in preserving biodiversity. The small patchy network of interconnected habitats, however, is swallowed more and more by new developments. Aruba is in many cases the owner of the spots that together constitute a '*green corridor network'* for local plant and animal species. Action to protect and preserve the natural green corridor would be in concordance with the Spatial Development Plan (ROP, 2009) that was first postulated in 2009, but is under consideration today.

Infrastructure in 2010 and in 1911

The distribution of distances[17] from home to work, measured in 2010, reveals a stressing pattern with consequences for the intensity of road use, traffic congestion and fuel consumption. Figure 14 summarizes the results that have been explained in detail in a previous paper (Derix, 2013b). The study shows that there is a local concentration of employees in several areas in the south that have to travel the longest routes to work (the daily distance to work for many that live in San Nicolas is as far as 23 km; a stretch that corresponds with a distance to the Hotel area in the north). In contrast, a majority of those who live in or near the center in Oranjestad and in San Nicolas cover the shortest distances to work (i.e. a distance that suggests that they live close to work). Those who live in the region of Pos Chiquito on average cover an intermediate distance of about 11 km to work (i.e. their destination of work may be in either direction, Oranjestad or San Nicolas). Also, those that live in the more rural areas, east of St. Cruz or far to the north, travel intermediate distances.

A layout for traffic congestion

Aruba is about 30 km in length and on average about 8 km in width. In this area of approximately 180 $km^{2,}$ close to *1,000 km* length of roads exists (Table 2).

At present, despite these many roads, the infrastructure turns out to be inadequate to cope with the daily traffic. Traffic, namely, suffers severe congestion in many locations, but most severely during rush hours in Oranjestad and in its surroundings. Oranjestad harbors primary schools and higher education centers (Derix, 2013b). As a result, Oranjestad attracts traffic from in- and outside the region. Furthermore, most parents bring their children to school by car, since the car is the prime mode of transportation to work as well as to school (Derix, 2013b). The percentage of parents that bring their children (across all ages) to school by car is noteworthy as many of the prime scholars actually live within only a short distance from the primary school (less than to 3 km). The result is that many parents get in and out of the city twice daily only to take their child(ren) to (often different) school(s) in order to pursue their way to work.

[17] The distance is based on the measure of Euclidean distance, i.e. as a straight line between home and work. No information was available on the actual route that is taken.

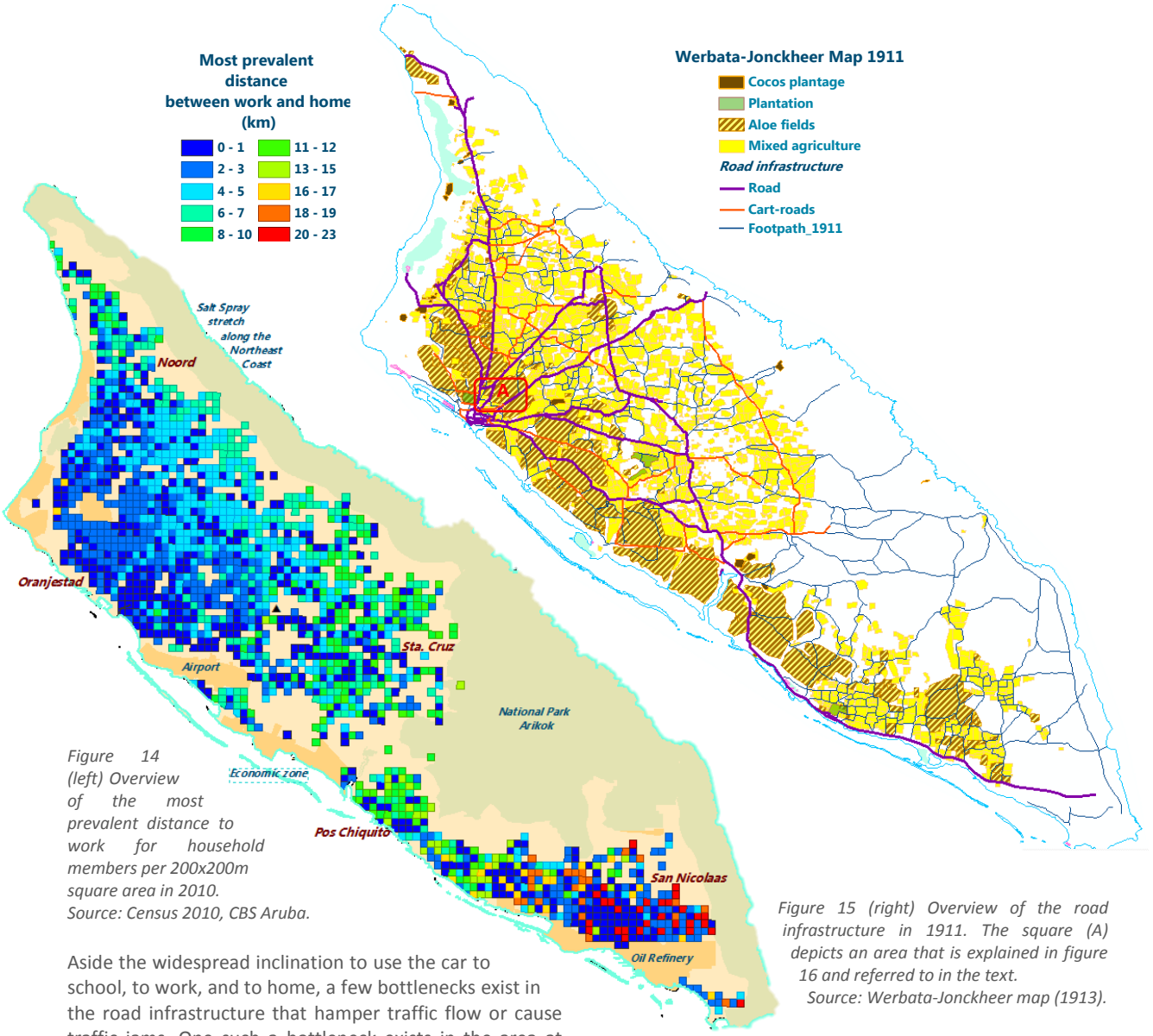


Figure 14 (left) Overview of the most prevalent distance to work for household members per 200x200m square area in 2010. Source: Census 2010, CBS Aruba.

Figure 15 (right) Overview of the road infrastructure in 1911. The square (A) depicts an area that is explained in figure 16 and referred to in the text. Source: Werbata-Jonckheer map (1913).

Aside the widespread inclination to use the car to school, to work, and to home, a few bottlenecks exist in the road infrastructure that hamper traffic flow or cause traffic jams. One such a bottleneck exists in the area at '*Frenchman's Pass*'/ '*Balashi*' and another is at the '*De La Salle Straat*' and at the '*L.G. Smith Boulevard*' in 'Oranjestad'. In these areas only few roads serve the transit of daily traffic flow between the areas north and south.

This has been recognized a long time ago already, but large infrastructure projects are hampered by a complexity of historic land ownerships and juridical conflicts about the expropriation of terrains. For instance, to ease the traffic flow in and around Oranjestad an additional third ring and an extension of the inner ring is portrayed that leads traffic around the city (Figure 16).

To understand what influences from the past may have added to today's traffic problems, we choose a historical perspective and compared the layout of the road infrastructure today with the situation in the past

The layout of the road infrastructures in Aruba dates back at least a hundred years ago, when the landscape in Aruba was dominated by agriculture and the local exploitation of phosphate and gold encouraged the development of better roads. From about that time, a hundred years ago, a relatively precise and schematic topographic map exists, the so-called Werbata-Jonckheer map (Krogt, 2006).

The map dates from 1913, but provides us with very relevant information about the extent of land use and road infrastructure that was collected during the period *1909-1911*.

The information from the map shows that the outline of the main road infrastructure a hundred years ago corresponds well to the outline of the main roads today (Figures 9, 15 and 16). Over the years, the land alongside the main road connections turned more and more into residential neighborhoods, but differences in early agricultural land use had a differentiating effect on the opportunities for development.

In 1911, a fine network of unpaved cart roads and footpaths connected effectively in all directions. Oranjestad was much smaller than today, but it was already the heart of activity and trade, and the paved road infrastructure radiated from its city center to the hinterland (figure 15 and 16). At the time, in 1911, vast Aloe fields surrounded Oranjestad and the few roads that ran through these Aloe fields almost had no interconnections. In early 20th century there was probably no need either for roads to run parallel to Oranjestad.

Roads - DOW layer 2013	Type name	Asfalt	Beton	Klinkers	Olie	Zand	Material Unknown	
IRF category		Paved	Paved	Paved	Unpaved	Unpaved	Unknown	
Highway, Main or National Roads	Autosnelweg	47,337	-	-	-	-	-	47,337
Highway, Main or National Roads	Autoweg	59,466	-	-	-	-	501	59,967
Highway, Main or National Roads	Hoofdweg c.q. hoofdroute	59,144	-	-	-	-	2,604	61,749
Other Roads - Urban - Rural	Wijkweg	32,198	-	-	-	2,309	6,201	40,709
Other Roads - Urban - Rural	Buurtstraat	48,744	-	1,097	1,137	19,285	12,239	82,503
Other Roads - Urban - Rural	Woonerf	80,142	1,508	3,712	8,171	101,288	22,139	216,960
Other Roads - Urban - Rural	Woonstraat	67,726	-	109	1,551	22,071	11,847	103,304
Other Roads - Urban - Rural	Type Unknown	96,867	668	8,355	4,749	200,524	74,395	385,557
	Length (m)	*491,625*	*2,176*	*13,274*	*15,607*	*345,477*	*129,927*	*998,086*

Table 2 Road Infrastructure in 2010. The table shows a summary of the length (in meters) of the road segments in Aruba in 2010 per type of pavement. The category 'unknown' sums the road segments that have not yet been appropriately addressed.
Source: DOW and CBS Aruba

At a distance from Oranjestad, however, many small cart-roads and footpath's can be observed and ran between the small agricultural terrains. This well-connected network of cart roads and footpath's spreads to every corner in the landscape (Figure 9, 15 and 16). Interestingly, also a fine maze of footpaths runs close to the center in San Nicolas. The map shows that the region of Savaneta up to San Nicolas, in contrast to the area close to Oranjestad Center, was dominated primarily by small agricultural terrains and with only few Aloe fields. A similar network of footpaths was neither present nor required obviously, so close to Oranjestad.

In this context, we like to recall the information in figure 8. A major part of the countryside (mainly quartz-diorite substrate) was exploited in relatively small agricultural terrains with a variety of land uses, whereas, along the west and southwest coastline (mainly Limestone substrate) large Aloe fields dominated the scene (with the exception of the area of Savaneta, Brasil and San Nicolas and along the dry-river beds, where the substrate was alluvial muds and sands). So, it is important to understand that the infrastructure at the beginning of last century served its purpose well in terms of the required mobility in relation to land use (small or large terrains and dispersed housing). There were probably only few cars on the island at the time and most transport was done with carts and/or donkeys.

In brief, on the map of early last century we observe a difference between the vast Aloe fields and the rest of the agricultural land in regard to infrastructure. Where Aloe fields dominate the land, houses were scattered and roads and footpaths were scarce and not present in all directions. In contrast, the small agricultural terrains were interwoven with a myriad of footpaths that ran between cacti and stone fences and rarely crossed the land itself.

Figure 16 highlights an area east of Oranjestad and is taken from the map in figure 15 (indicated by square A). We added relevant information about the road infrastructure in 2010, as well as type of land use in 1911.
Whereas the fine maze of interconnections directly surrounding the center of San Nicolas offered good opportunities to develop, over the years, into a well-organized road infrastructure, the road infrastructure in and near Oranjestad was lain out to serve traffic in and out of Oranjestad, but was not suitable for transit traffic. As most roads were radially oriented, the large terrains in the vicinity of Oranjestad blocked transit traffic. In time, footpaths and cart-roads turned into roads, but their absence in the vicinity of Oranjestad made a natural transition to the road infrastructure that would explain today's challenges.

In time, as the agricultural terrains and Aloe fields were parceled one by one and transformed into new neighborhoods, the access in and out of the residences frequently did not interconnect to the roads from neighboring terrains. The delicacy of private ownership of the terrains involved may be the cause why the road infrastructure has never been subjected to drastic changes afterwards. Even today, it is extremely difficult to expropriate landownership to enable the development of an apt road infrastructure that meets today's requirements.

The snapshot of the overlay of maps from 1911 and 2010 in figure 16 exemplifies some of the consequences from the agricultural situation in early century. The colored background of the roadmap represents the historic location of Aloe and small cacti or stone fenced terrains. The parceling of the large Aloe fields likely resulted in large residential areas, whereas smaller residential areas today are located where former small agriculture terrains existed. Between these terrains, small wildered plots still do exist. Today's primary road system (colored in white) corresponds well to the roads and cart-roads from 1911 (colored in red and respectively in dark blue). Even the footpaths from 1911 (colored in light blue) correspond well to some of the roads in 2010.
So, in general, a paved road in 1911 became a main road in 2010 and a cart-road became either a main road or a secondary road. Also a number of the footpaths from 1911 turned into secondary or residential roads in 2010.

In figure 16 we show a snapshot of an area northeast of Oranjestad between the outer ring of Paradera and the inner ring of De La Salle Straat. Of the three radially oriented main roads that ran from Oranjestad eastwards, we labeled all road intersections by colored dots (see the caption of figure 16 for further explanation about the difference in color).
The map shows that there are only few cross-intersections (blue dots) and thus ample opportunity to connect in parallel to the center of Oranjestad. Only in a few occasions cross-intersections exist, but most of the residential roads end as a T-junction to the main road network.

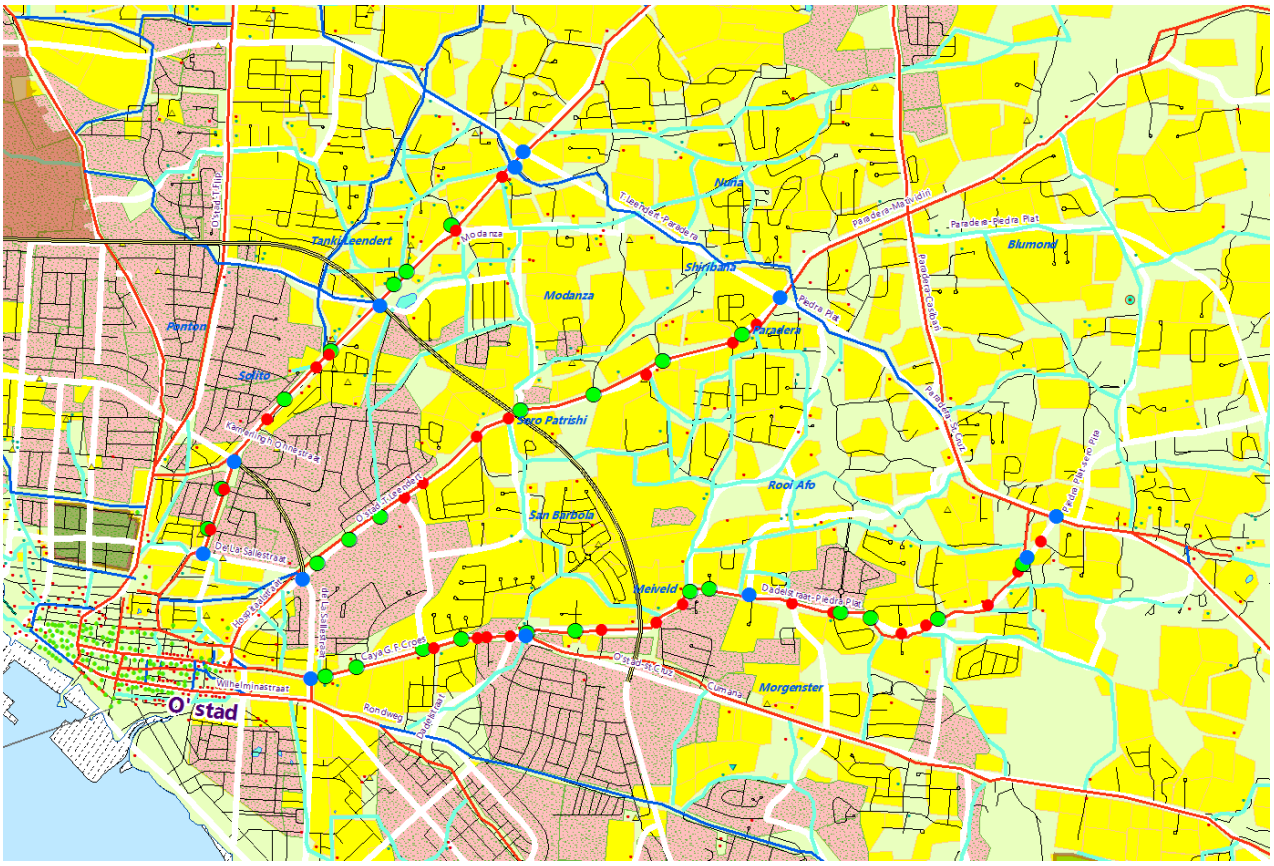


Figure 16 shows an overlay of the road infrastructures in the surroundings of Oranjestad in 2010 with information from 1911, based on the Werbata-Jonckheere map (Werbata, 1913). We focus on an area east from the center of Oranjestad. The pink and yellow colored backgrounds represent the extent of respectively Aloe fields and cacti- and stone fenced agricultural terrains in 1911. The lines (colored red, blue and light blue) represent respectively the paved roads, the unpaved cart-roads and the footpaths from 1911. The road infrastructure from 2010 is highlighted by white (main roads) or thin grey lines (residential roads).The projected inner ring extension and additional third ring is indicated by a brownish colored line segment, encircling Oranjestad.
For each of the three radially oriented main roads in 2010, as indicated in the picture above, we labeled the road junctions by colored dots. A red dot indicates an intersection with an access from the south to the main road. A green dot indicates an intersection with an access from the north and a blue dot indicates a cross- intersection. For further reading we refer to the text.

The few cross-intersections that do exist are likely used as shortcuts through residential areas, as there appears to be some level of inconvenience from local traffic in these neighborhoods (Derix, 2013b).

An improvement of the interconnectivity between south and north of Oranjestad is planned already (see figure 16), but is hampered by the required expropriation of terrains and housing. An extension of the inner ring is schematically projected as well as an additional third ring that will run parallel to Oranjestad, between the (outer) ring of Paradera and the (inner) ring of De La Salle Straat (Aruba, 2013) (DIP, 2009).

Final remarks

The review of land use in past history stresses the idea that the presence of large Aloe cultivation fields and small-scale cacti or stone fenced agricultural terrains had a differential impact on the location of current residential and road developments. In 1911, the infrastructure was adapted to the agricultural exploitation of the landscape and the orientation towards Oranjestad, whereas today, the infrastructure requires an orientation alongside Oranjestad as well. To some degree, we may conclude that the layout of traffic problems today already had been shaped by the size and orientation of the agricultural terrains in the past, and thus, by the composition of the soil substrate that defined the type of land exploitation in the first place.

No one in early last century, however, could have foreseen the development of the tourism industry at the northwest coast and the level of suburbanization today.

We like to emphasize that situations in the past have the potential to act as a matrix for subsequent developments. The example above, in which we suggest an influence from the type of agricultural subsistence on later road development and traffic issues even a century later, makes clear how important it is to have some historical notion and understanding of the interconnectedness between events in time.

We will also deliberate on the significance of a multisector approach in problem-solving. Information tools such as GIS technology that base on the spatial location of information have grown in importance.

Our findings that show a strong association between the location of Aloe cultivation on the Limestone Terraces and the location of small cacti and stone fenced agricultural terrains on the Aruba Batholith and fertile alluvial mud and sand deposits on the larger dry-river beddings in 1911, was analyzed with the use of GIS technology. Modern GIS technology provides the means to exchange, combine and analyze information from different fields, including geological, historical, economic and environmental data, and helps to better understand the challenges that we face.
To be able to have access to up-to-date information from a variety of fields and different expertise, we need to organize and maintain a library of compatible information, under guidance of a dedicated central authority, with its focus and the management and maintenance of such a GIS-based framework for collaboration and information sharing.

It is our belief that the multidisciplinary use of detailed local spatial information is essential to better understand and be able to tackle the environmental issues at the societal and economic interface that we face today in Aruba. This paper is part of a series on the Aruban landscape and focuses on information from history and land use in particular.

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