ASSESSING THE AVAILABLE LAND AREA FOR URBAN AGRICULTURE ON THE HALIFAX PENINSULA

Anita Nipen
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TABLE OF CONTENTS

1. Introduction 5
1.1. Research Problem 5
1.2. Topic Significance 5
2. Literature review 9
2.1. Availability of land and urban agriculture in Halifax 9
2.2. Alternative measures 10
2.3. Energy reduction in Halifax 12
2.4. Community gardens and benefits of urban agriculture 12
2.5. Sun requirement and Shading 14
2.6. GIS and LiDAR in landscape analysis 15
3. Methodology 16
3.1. Space availability 16
3.2. ShadeD relief 17
3.3. Limitations 23
4. Results 24
4.1. Space availablity 24
4.2. ShadeD Relief 25
5. Analysis 32
6. Limitations, Recommendations, ConclUsions 34
7. References 36
8. Appendix 41
Histograms of yard Sizes Exposed to Sun 41
GIS Data Sources 49

Table of Figures and Tables

Figure 1 Elevation Map (HRM 2007)......18

Figure 2 ShadeD Relief (HRM 2007)......19

Figure 3 Shadows (HRM 2007)......19

Figure 4. Map of areas of study (HRM 2007)......20

Figure 5. Percent of lot shaded at 10:00, area 1......25

Figure 6. Percent of Lot Shaded at 13:00, Area 1......26

Figure 7. Percent of Lot Shaded at 16:00, Area 1......26

Figure 8. Avergae percent of lot in shade, Area 1......26

Figure 9. Percent of Lot Shaded at 10:00, Area 2......27

Figure 10. Percent of Lot Shaded at 13:00, Area 2......27

Figure 11. Percent of Lot Shaded at 16:00, Area 2......27

Figure 12. Average Percent of Lot in Shade, Area 2......28

Figure 13 Percent of Lot Shaded at 10:00, Area 3......28

Figure 14. Percent of Lot Shaded at 13:00, Area 3......28

Figure 15. Percent of Lot Shaded at 16:00, Area 3......29

Figure 16. Average Percent of Lot in Shade, Area 3......29

Figure 17. Percent of Lot Shaded at 10:00, Area 4......29

Figure 18. Percent of Lot Shaded at 13:00, Area 4......30

Figure 19. Percent of Lot Shaded at 16:00, Area 4......30

Figure 20. Average Percent of Lot in Shade, Area 4......30

Figure 21. Percent of Lot Shaded at 10:00, Area 5......31

Figure 22. Percent of Lot Shaded at 13:00, Area 5......31

Figure 23. Percent of lot shaded at 16:00, Area 5......31

Figure 24. Average Percent of Lot in Shade, Area 5......32

Table 1 Shade tolerance of common garden crops (Olkowski 1979)......15

Table 2 Average percent of shading......32

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1. INTRODUCTION

1.1. RESEARCH PROBLEM

This study explored the potential for urban agriculture in Halifax, Nova Scotia. Land availability on the peninsula (districts 11-14) was examined. There are limitations to urban agriculture, such as rain, space, and sunlight availability, as well as soil conditions and contamination. This study focused on land and sunlight availability. It was limited to an investigation of on-ground gardens and the cultivation of crops. Although other methods of urban agriculture, such as green roofs, and livestock and beekeeping, can exist within the city, these were not be explored in this study. This study aimed to answer two questions: 1.How much viable urban agricultural space is available for on-ground gardens in yards and vacant lots on the Halifax Peninsula? 2. To what extent does shading limit the potential for urban agriculture on the peninsula? The overall goal was to establish a better understanding of the potential to produce food in the urban environment in Halifax.

1.2. TOPIC SIGNIFICANCE

The World Wide Fund For Nature's (WWF) Living Planet Report of 2008 shows that more than ¾ of the world's population live in countries where the national consumption is higher than the biocapacity of the country. WWF reports that global consumption exceeds the Earth's regenerative capacity by approximately 30%. The ecological footprint is the sum of the resources needed for a country's consumption, space for infrastructure, and space and energy needed for waste absorption, expressed as a land area in hectares. Areas examined are the built land, fishing ground, forest, grazing land, crop, and carbon footprint.

The national ecological footprints vary, and reflect the global inequality of resource consumption. In Canada, the footprint is increasing, while some other countries see a decrease. The total footprint of the countries in Africa has dropped by 19% over the past 40 years. (WWF) Canada's footprint is 7.1 ha/person (WWF 2008) and Halifax's is 7.83 ha/person (Wilson 2005). The footprint is reduced by decreasing the consumption of energy, biomass and water. Authors of the report suggest that lifestyle changes can prevent an ecological recession, the depletion of natural resources to the extent where future generations are endangered, which is an effect of living beyond the means of the planet. These include alterations in energy strategies and personal consumption habits, and urban design that encourage energy reduction. (WWF)

Projecting current global consumption trends into the future shows resource demand in 2030 to be twice the biocapacity of the Earth. (WWF) To prevent future generations from living with ecological debt, resource consumption habits must be altered for societies to become more sustainable. According to Newman, sustainability meets "the needs of current and future generations through integration of environmental protection, social advancement and economic prosperity" (Newman 2007). Reconstructing societies towards sustainability has been an ongoing process, and sustainability is a key term in planning strategies, both at local and global levels. For instance, a target of the Millennium Development Goals set by the United Nations for 2015 is to ensure environmental sustainability through an incorporation of sustainable development principles in policies and programmes (UN 2009). At the local level, HRM's Community Energy Plan (CEP) of 2007 incorporates sustainability in energy strategies (HRM 2008). A sustainable society assures the availability of resources for future generations, by protecting resources from overexploitation. Due to the overshoot of consumption, current consumption habits do not protect resources for future generations.

In the younger stages of present day cities in Canada, farms were located around the periphery of towns, and as cities grew, this arable land was turned over to urban development. Not only is the availability of croplands threatened by urban development, but highly intensive agriculture causes environmental degradation and loss of productivity of croplands (Tegtmeier 2005). The demand on the Earth for resources is increasing, and arable land per capita is decreasing (WWF).

Over the past century, the food supply system in Canada has changed drastically. Industrial farming has largely replaced family farms, and the average farm size has increased while the number of farms has decreased. The local and regional farmer's place in the food system is reduced with the globalisation of the food system (Gottlieb 2002). Carbon dioxide emissions from the transportation of food increase as the reliance on imported food becomes stronger. In 2001, only 12% of the fresh fruit and 51% of fresh vegetables consumed in Canada were grown in Canada (Stat Can 2001). Only 8.4% of the total spending on food in Nova Scotia goes to Nova Scotian farmers (NSFA 2008, Stat Can 2009 a).

The current system relies on imported food, much of which does not guarantee the rights of the workers (Robbins 2004). Forcing developing countries into the global market through the food system has proven to be detrimental, and has contributed to marginalisation and environmental degradation, as Robbins describes in various case studies. Furthermore, global food systems promote social injustice by taking advantage of farmers in developing countries.

Gottlieb states that food issues “reside directly at the intersection of the social and ecological, where social justice and environmental justice movements can meet.” Urban agriculture is a tool for challenging the current globalised food system. Safeguarding the security of future generations, the current and future health of the global and local ecosystem, and the rights of worldwide farmers is incentive to drive society toward sustainable practices.

The demand on croplands can be reduced by growing crops in urban settings where land is available for cultivation. This does not require the conversion of valuable natural habitats, such as forests or wetlands, but rather uses underutilised, derelict, or vacant land. The benefits of urban agriculture have been documented widely, and include environmental, social, economical and structural benefits.

Urban agriculture is the production of food through crops, fruit and nut bearing trees, livestock, and bees within a city. Crops are grown in on-ground gardens, in pots, without soil through hydroponics, on green roofs and vertically along walls. Urban agriculture has appeared in various forms. European allotment plots have for decades been part of the urban setting. Urban agriculture has been used as a response to crises and changes in policies affecting food supply, such as relief gardens of the depression, victory gardens of World War II (Gottlieb 2002) and food shortages in Cuba due to changes in relations with the Soviet Union and the US (Nelson 2007). A decline in community gardens occurred after World War II in North America, as the food shortage of the war was alleviated. The 1970s saw a resurgence of community gardens, due to questions of community identity and concerns of fossil fuel dependence (Gottlieb 2002).

Limitations to sustainable lifestyles must be overcome. It is recognised that urban agriculture is a method of reducing energy consumption. This study aimed at describing the amount of land available for urban agriculture on the Halifax peninsula, which would be an indication of whether urban agriculture can feasibly be considered an applicable method for altering lifestyles towards sustainability in Halifax. An initial review of aerial maps of the peninsula and observations from a walking survey reveals that even the most metropolitan areas of Halifax have islands of green spaces, and that many homes on the peninsula in central Halifax have relatively large backyards. With few tall buildings to block sunlight, and a steady supply of rainwater, it is anticipated that many of these yards could be utilised for food production. A realisation of the city's potential can drive the movement towards greater implementation of agricultural practice in Halifax.

2. LITERATURE REVIEW

2.1. AVAILABILITY OF LAND AND URBAN AGRICULTURE IN HALIFAX

Urban agriculture is practiced throughout the city, and there are numerous community gardens, such as Seymour Green on the Dalhousie University campus, the North End Community Garden, and the Gorsebrook Garden. Halifax Landshare is an initiative to connect growers looking for land and landowners who wish to share their land with growers (EAC 2009).

Agriculture was practiced on the peninsula by European settlers upon their arrival. Scottish settlers, comparing the peninsula to their homeland, deemed it unfit for agriculture, due to the thin, stony soil. John Young, however, demonstrated in the early

1800s that agriculture is possible on the peninsula. Young farmed his 25 hectares west of Agricola Street, which was on the outskirts of the town at that time (MacKenzie 2004). In 1838 there were 776 acres of hay, 160 acres of potatoes and turnips, 156 acres of oats, and 82 acres of wheat on the Halifax peninsula (Gwyn 1998). In the first half of the 1800s, the population increased fivefold in Atlantic Canada, and Nova Scotia's agricultural imports began to exceed exports (Gentilcore 1993) .

Challenges to urban agriculture include physical and social factors. Urban agriculture may be met with reluctance, due to associated negative perceptions and stigmas. Land may be unavailable due to its intensive use for buildings, or it may be unsustainable for cultivation due to physical conditions, including soil quality, soil contamination, or lack of rain or sunlight, soil quality. The soil on the peninsula is predominantly thin and stony, (Goodwin 2002) and unsuitable for certain vegetables. Soil contamination has been observed on the peninsula. Iron, zinc and lead levels have exceeded the Canadian Council of Ministers of the Environment's (CCME) standards for contaminant concentrations in some plots of land associated with food production. (CCME 1999(a,b), Saunders 2009)

There is currently no literature available that summarises the amount of land available for agriculture in the central urban core of Halifax Regional Municipality in recent times. To begin to understand the potential for food production in this urban area, it is necessary to estimate how much land is available, in terms of surface area and access to sunlight.

2.2. ALTERNATIVE MEASURES

There are alternative methods of growing crops in areas where land is not available or the soil is not suitable. Planters and pots can contain uncontaminated soil, and can be moved around to appropriate areas. Raised beds are permanent fixtures that separate the growth soil from contaminated soil by building up from the ground. Impermeable layers can also be placed as separation from contaminated soil. Grow bags, seeds and soil placed in slit bags, can be partially buried in the ground (Saunders 2009). Hydroponic gardens, growing plants without soil in a nutrient solution, can be built on the ground, rooftops, balconies and other structures. Hydroponics, compared to on-ground gardens, can use fewer resources, increase yield per unit area, and reduce water use by 90% (Bradley 2000).Modern green roofs, rooftops with vegetative growth, emerged in Germany at the turn of the twentieth century (Köhler 2003, Oberndorfer 2007). Green roofs can lengthen the life span and lower the life cycle cost of roofs (Porsche 2003), and may also improve sound isolation (Dunnett 2004, Oberndorfer). Green roofs can reduce the amount of energy needed for heating and cooling of buildings. The heat island effect occurs when urban areas are warmer than surrounding rural areas. The effect results from a reduction of the city's solar reflectance, by using construction materials with high specific heat capacities. Heat is retained within the city, increasing the need for air conditioning in the summer to cool buildings. The addition of plants so surface areas can increase the surface albedo of the city (Marceau 2008). In order to construct green roofs, the roof must be able to bear the load of the soil and plants. This varies depending on the structure of the house, and it is therefore not possible to establish estimates of green roof availability unless examinations of individual buildings are conducted. Numerous countries in Europe require the structural integrity for green roofs in new developments. The ability of plants to grow vertically can be taken advantage of through green walls. These plants have a lower load- bearing strain, and can be used to maximise crop cover in sunlight when green roofs are not possible due to the structure of the building (Durst 2007).

2.3. ENERGY REDUCTION IN HALIFAX

Halifax Regional Municipality (HRM) has made a commitment through the Partners for Climate Protection to reduce greenhouse gas emission levels by 20% by 2012, compared with 2002 emission levels (PCP 2008). In addition, HRM has implemented other environmental sustainability strategies, such as the Community Energy Plan (CEP), the Clean Air Strategy, and Climate SMART (HRM 2009). HRM relies heavily on imported non-renewable energy sources. Making changes to HRM's energy strategy is seen as a vital step in reducing greenhouse gas emissions in HRM. HRM and Natural Resources Canada created the CEP in 2007. The CEP proposes strategies for reductions in energy consumption in HRM, and includes a list of 40 recommended actions. The plan is recognised by HRM officials as a benefit to the environment and as a method of reducing energy costs. One of the specified goals is to encourage energy efficient land use planning and neighbourhood site planning. Urban agriculture is one of the suggestions, and it is proposed that urban agriculture can meet energy needs in the greenest, leanest, cleanest way possible (HRM 2008).

2.4. COMMUNITY GARDENS AND BENEFITS OF URBAN AGRICULTURE

The benefits of urban agriculture expand beyond the environmental benefits. Mental and physical health can be improved by practicing agriculture. The addition of greenery to the city can have positive effects. Studies have shown that exposure to plants improves mood and alleviates stress (Shibata 2002, Ulrich 2002). As food prices are increasing, urban gardening can alleviate the financial burden of food. Backyard crops will not suffer degradation associated with long transport, such as damage from vibrations (Zhou 2007). Vegetables and fruit can ripen on plants rather than in a truck. Since Halifax has a bylaw restricting pesticide use (HRM 2003), negative effects of pesticides, such as contamination of groundwater, would not be an issue for crops grown within the city.

Community-based urban agriculture can result in a stronger sense of belonging, involvement and inclusion, and may fortify community identity. Bonds are created between community members by sharing work, land and crops. Urban gardens can encourage social networks, improve the appearance of the neighbourhood and increase pride in the neighbourhood, as Armstrong (2000) concluded from a study on community gardens in upstate New York. Participants in the study indicated reasons for partaking in community gardens, the most common being the availability of fresh food, mental health benefits, and a chance to enjoy nature and open spaces. The networks established from community gardens may encourage further community-based problem solving. Ownership pride may boost the intrinsic value of the neighbourhood. Community gardens enable those without access to land to participate in gardening.

Vacant lots and derelict areas may be potential areas for agriculture, as is being shown in Detroit, a city with extensive tracts of vacant lots and abandoned buildings. In 2006, up to 40% of some residential areas had vacant tracts (Kim 2006). The city grew around the automobile industry. With the economic problems that General Motors Corporation and Ford Motor Company face, the numbers of vacant plots of land are increasing (McKee

2008). In 2004, empty lots composed one third of the city's area (IPT 2004). The city utilised these empty spaces for food production, and there are now more than 500 productive urban gardens, and the numbers are increasing exponentially (McKee).

2.5.SUN REQUIREMENT AND SHADING

Plants require sunlight for energy and developmental stimulation (Larcher 1995). Plant characteristics, such as leaf size, resource allocation, and branching, alter depending on the amount of sun the plant receives (Wiebel 1994). Insufficient lighting may result in unproductive plants. Full sun, which involves direct sun from circa 9:00 to 16:00 o'clock, is preferred by most crops (Olkowski 1979). Studies show an increase in the dry weight production of plants proportional to increases in sun intensity. However, at high intensities, the productivity decreases, especially of shade-tolerant varieties (Issarakraisila 2008, Shirley 1926).

Some plants are more shade tolerant than others. Generally, plants harvested for the leaves are more shade tolerant than plants harvested for the fruit or root. The following table from Olkowski, displays common crops and their shade tolerance. Gardens can be designed to utilise available sunlight efficiently, for instance by planting climbing varieties such as cucumbers and beans in areas where most sunlight is projected above the ground, and low-growing crops such as lettuce and kale in areas that receive sunlight on the ground (Olkowski 1979).

TABLE 1 SHADE TOLERANCE OF COMMON GARDEN CROPS (OLKOWSKI 1979)

Maximum light	Slightly tolerant of shade	Moderately tolerant of shade
Tomatoes Corn Squash Peppers Cucumber Beans Eggplant	Cabbage Broccoli Kale, collard greens Beets Turnips Radishes Onion Carrots	Lettuce Endive Spinach Sorrel Mint herbs

2.6.GIS AND LIDAR IN LANDSCAPE ANALYSIS

Geographic Information Systems (GIS) is a valuable tool for examining land-use potential. It has been used for a broad variety of analyses, such as technology adoption and land use on dairy farms in Kenya, (Staa 2002), land available for development in the Beirut Metropolitan Area (Abed 1994), and future land use in the Netherlands (Schotten 2001). GIS has been recommended for identification of potential land for urban agriculture. This has been done in Rosario in Argentina, where ownership of land, land-use regulations, soil quality and contamination, and accessibility were studied in part through GIS. GIS work has also been conducted in Cagayan de Oro in the Philippines (Veenhuizen 2006) and in Accra in Ghana (Larbi 2005, Veenhuizen 2006). In the city of Governador Valadares in Brazil, urban development plans recognised urban agriculture as a legitimate use of urban land, and urban agricultural areas were included in GIS databases (Veenhuizen 2006).

GIS is an important tool for landscape analysis. Veenhuizen lists methods for governments to enhance access to land for urban agriculture, such as designating vacant lots for urban gardening groups, encouraging owners of vacant land to lease land to urban food growers, the creation of inventories of available land and testing of suitability of land for urban agriculture. In Cienfuegos, Cuba, Piura, Peru, and Dar es Salaam, Tanzania, GIS and participatory methods were used to assess suitability of vacant land for agriculture and to create an inventory of vacant land (2006). Rasmussen *et al.* (1999) demonstrated the use of GIS as a means of recognising grazing limitations. Suitable grazing grounds were mapped from topographic maps and landcover maps from satellite images, in order to aid Mongolian pastoralists in sustainable management of common pastures.

GIS-based 3-dimensional urban models are gaining prevalence in ground surface information acquisition (Priestnall 2000). Lin (2005) describes the advantage of LiDAR (Light Detection and Ranging) in providing a more accurate depiction of building heights than aerial photographs in studying urban areas. Lin used LiDAR data to create models of the seasonal solar radiation patterns in downtown Houston, Texas.

3. METHODOLOGY

3.1.SPACE AVAILABILITY

Geographic Information System (GIS) was used to determine the amount of available space for urban agriculture. The Map and Geospatial Information Centre (MAGIC) at Dalhousie University provides topographic data of Halifax Regional Municipality (HRM) from the HRM database from 2007. ArcMap is used for mapping and analysis. The data for HRM has high resolution, therefore showing a lot of detail. The relevant layers used were satellite images of the peninsula, layers of the peninsula/harbour boundary, property parcels, park areas, vegetative areas, recreation areas, roads (including driveways and paved yards), railroads, building polygons, and trees. Other factors may be important for calculating available land, such as rivers, lakes and streams, but these are not present in the area of study. In the ModelBuilder, railroad tracks, buildings, paved surfaces, parks, recreation areas are cut from the property parcel layer. The new model shows the yards with vegetative cover. The new layer was manually examined to ensure only areas constituting yards were included. In the case of apartment buildings, the communal space, if present, was accounted for as one yard. The shading trends derived from the GIS analysis, further explained in section 3.2, are extrapolated to the entire peninsula. The average shading is used as a measure of land reduction due to shading. The total area is calculated, which represents total land which can potentially be used for agriculture, without considering variables that might hinder urban agriculture, such as soil contamination, and steep slopes. Statistics Canada provides information on average vegetable and fruit yields for all provinces. 2008 average yield figures for selected vegetables will be used to create an economic depiction of the land availability by relating it to potential yield.

3.2. SHADED RELIEF

LiDAR can depict various topological features, and has been used for coastal zone mapping, viewshed analyses, watershed boundaries, and changes in topology over time. The GIS Centre at Dalhousie University used LiDAR elevation data to display a shade model of the Halifax Public Gardens (Jahncke 2009). LiDAR depicts topology through laser light pulses. Scanning LiDAR systems, as used in this study, combine airborne sensors, GPS and IMU (Inertial Measurement Unit) (Kemp 2008). Laser lights from an airplane measure the elevation of ground objects by calculating the distance between the airplane and the object through the time it takes for the light to meet the ground cover.

LiDAR data can be processed in software such as ArGIS. In this study, the LiDAR data was used to measure the amount of shading in backyards, by measuring the height of buildings and dense vegetation. Given the elevation differences of buildings, vegetation and the ground, the shading cast by taller structures on the ground can be measured. **Error! Reference source not found.** is an elevation map created from LiDAR. The lighter areas correspond to higher elevation areas, and darker areas represent lower elevations.

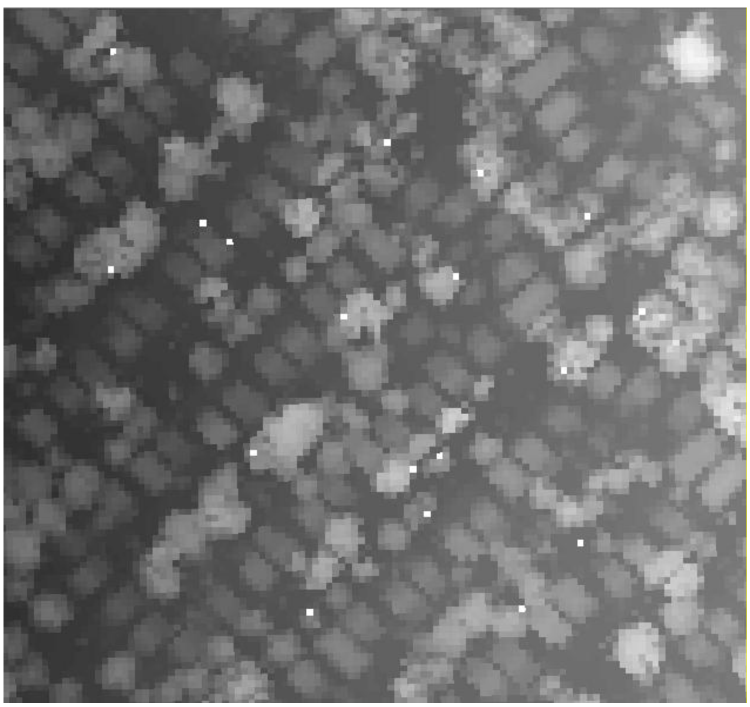

FIGURE 1 ELEVATION MAP (HRM 2007)

In Figure 2, the *hillshade* function creates a shaded relief map of the same area.

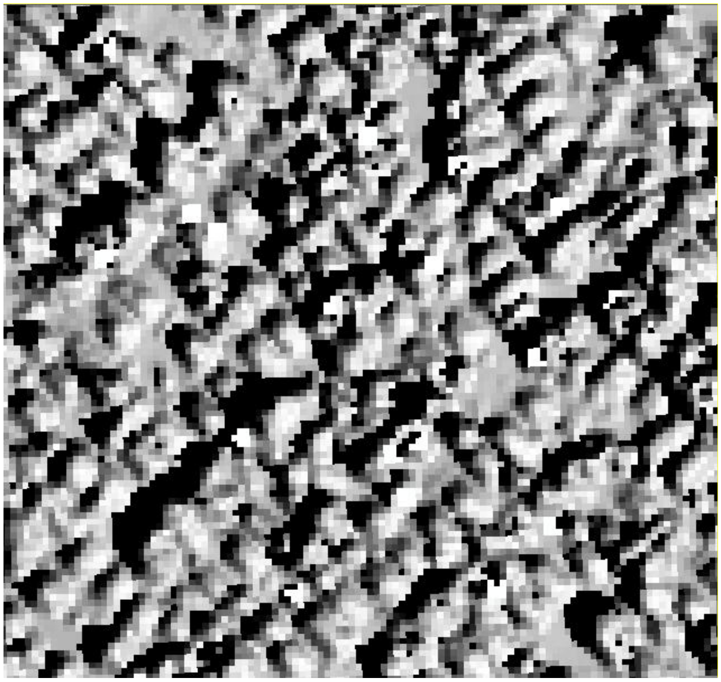

FIGURE 2 SHADED RELIEF (HRM 2007)

In **Error! Reference source not found.** below, only the shadows from the shaded relief are shown. These are cells that are in the shade of another cell.

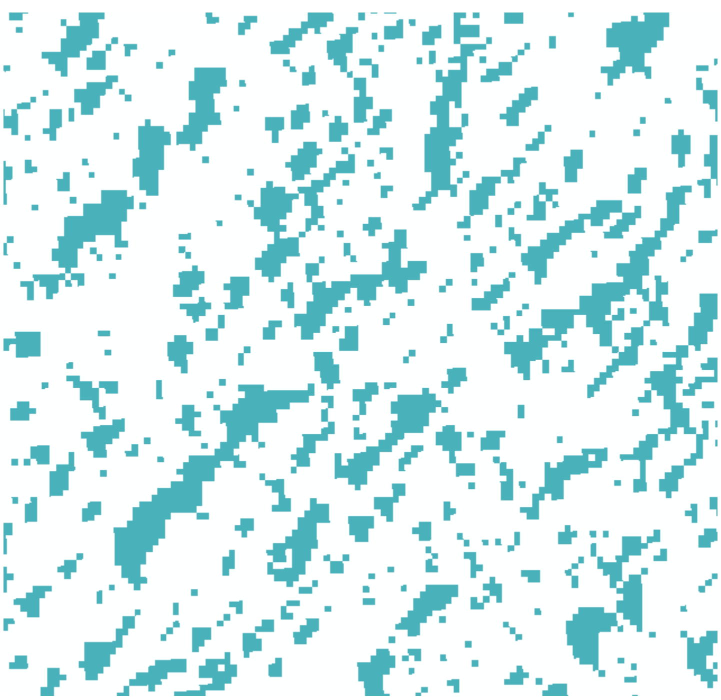

FIGURE 3 SHADOWS (HRM 2007)

Since LiDAR tiles contain a lot of information and take a long time to process, the amount of sun exposure was tested for six areas on the peninsula, three in the northern and three in the southern part of the peninsula, ensuring that study sites were distributed amongst various neighbourhoods. The peninsula was divided into north and south along Quinpool Road. A numerical grid was overlaid, and areas were randomly chosen through the random number application in excel. The six areas chosen randomly are displayed in Figure 4**.** Area 5 and 6 fell within the same tile, therefore five LiDAR tiles were examined.

FIGURE 4. MAP OF AREAS OF STUDY (HRM 2007)

The amount of sun to which a yard is exposed is specific to the position of the sun. Therefore, the specific day and time of observation were predetermined. The study of sun exposure was delimited to one day of the year, the middle of the growing season, 25 July. The amount and direction of sunlight varies throughout the day, therefore 3 times of the day were observed. The hours of sunlight were divided equally, and calculations of sun exposure were made at 10:00, 13:00, and 16:00.

LIDAR data files from the HRM database were collected from the Dalhousie Map and Geospatial information Collection (MAGIC). The information was used to measure the areas exposed to sun during three times of the day. Halifax and Musquodoboit were surveyed with LiDAR by PHB Technologies / LaserMap Image Plus. A total area of 1400 km^2 was surveyed over 6 flights in a Les Leves Aeroscan aircraft, registration number C-GOVX between 12 and 15 May 2007. The flying height was 1200 m above ground, at an average speed of 70m/s. The GPS base station at the Natural Resources Canada (NRCAN) in Halifax was used for LiDAR calculations. Ground profile surveys revealed an accuracy within 15cm of elevation. ArcGIS 9.2 was used for data processing. LiDAR data is divided in tiles, each covering an area of 1 km^2. There are 32 tiles on the Halifax Peninsula. These tiles cover more than the 20 km^2 of the peninsula.

The LiDAR data used in this project were retrieved from the HRM database through the Map and Geospatial Information Collection at Dalhousie University. LiDAR data is given in a text file, which is converted to a CSV file in order for ArcGIS to recognise it. After converting it to a Shape File, it is converted to grid, with cellsize 2 and a *mean* cell assignment type. In spatial analyst, the *hillshade* tool was used. The *hillshade* function creates a display of the elevation variations of a landscape. It shows areas that are shaded, depending on the sun's position, which is determined by the altitude, latitude, longitude, date, and time of day. Shaded areas change during the day due to the position of the sun. From the azimuth and altitude, the *hillshade* function depicts the shaded areas. The azimuth and altitude were calculated from the latitude, longitude, year, month, day, time zone, and time of the desired observation, using the online *Azimuth and Altitude Calculator for the Sun* from http://jamersbass.com/sunform/aspx.

In the *hillshade* function, the azimuth and altitude were inserted, and *model shadows* was enabled, which displays the shadows cast. In the new Shape File, the cells are coded with integers from 0 to 255, and those that are less than 1 are cells that are in the shadow of another cell. In order to only display the shadows, cells coded with 0 values are reclassed with a value of '1,' and all other values reclassed to 'NoData.' The resulting Shape File displays areas that are in shade. This raster file representing shaded areas was then converted to a vector file, which was then erased from a Shape File that displayed the yards without buildings and roads. The resulting vector file showed the unshaded land area in yards, having subtracted the shaded areas, roads, driveways, and buildings. From the attribute table, information about size of the unshaded land area was derived and processed for statistical analysis. The attribute tables contained information regarding the total area in shade and the size of the yards, which was used to create histograms showing the frequency distribution of shading trends.

3.3.LIMITATIONS

There were several limitations to the study. Sun exposure was only measured for one day, and the amount of shading would differ earlier and later in the growing season. Since the LiDAR data measured dense vegetation only, some vegetative areas would not be accounted for. Although these are less dense, they would nevertheless provide shade. Fences are not properly displayed in LiDAR data, since there are difficulties measuring vertical surface areas. These limitations mean that the shaded areas are likely to be somewhat larger than the LiDAR data indicate.

There have been changes since the 2007 data collection, such as construction of new buildings. Some driveways and paved yards are not displayed in the data. There are further factors that limit the possibility for crop cultivation in yards which are not accounted for, such as the microclimate of the yard, soil quality, and contamination. Sun exposure is also limited by cloud cover, and the study assumes full sunlight. The results are therefore favoured towards optimal days and the shading is slightly underestimated. Nevertheless, shading does not deem a yard unacceptable for agriculture, since shade tolerant species and optimal sunlight allocation through garden design are tactics which can result in cultivation despite lack of abundant sunlight. The study does not take into consideration areas that are suitable but unrecognised by LiDAR data, such as balconies for pots.

Delimitations placed on the study included a focus on a select few areas of the peninsula, measurements of one particular day, and on-ground agriculture. Other urban agricultural practices, such as hydroponics, livestock and bees were not considered. The study focused solely on private yards, and did not consider public space or vacant lots.

4. RESULTS

4.1. SPACE AVAILABLITY

After erasing obstructing features from a map of yards, it was determined that 4,084,793 m^2 (4 km^2) of the 20 km^2 peninsula are areas that are vacant of built structures. The GIS analysis, further described in section 4.2, showed that the five observed areas had an average of 22% shade cover. Shaded areas are not necessarily unsuitable for cultivation of crops, since there may be adequate sunlight at other times of the day. Shading during one part of the day does not eliminate the potential for crop cultivation. Unsuitability of land due to shading will be determined by the total amount of sunlight received at a given area, and the time of day it is received. The figure is likely an overestimation of the shading, since the variation in location of shading is not represented. Assuming a 22% loss of yard space due to shading, the 4 km^2 is reduced to 3.2 km^2, which is the unobstructed yard space that could potentially be used for urban agriculture. This calculation does not take into consideration the suitability of the soil, slope of property, vegetative cover and contamination.

A benefit of growing one's own food is the availability of fresh vegetables. Some vegetables preserve better than others, and vegetables such as lettuce are more appealing fresh from the yard. Lettuce is a shade tolerant crop, and suitable for the predominantly thin soil on the peninsula. Statistics Canada (2009 b) reports that in 2008, the commercial production of lettuce in Nova Scotia was 80 tonnes on 20 hectares, which amounts to 4000 kg/ha. Using this yield value, on 3.2 km^2, 1280 tonnes of lettuce could be harvested.

Statistics Canada reports that in 2001, average lettuce consumption by Canadians was 11.05 kg/year. (Stat Can 2002) Given the 2001 peninsula population (districts 11-14) of 58,466, 646 tonnes of lettuce are needed annually for the peninsula population, which is less than the potential yield of the peninsula yards.

The average yield of potatoes in Nova Scotia is 23.54 tonnes/ha (Stat Can 2009 c). The 3.2 km^2 of the peninsula would yield 7532.8 tonnes of potatoes annually. According to statistics Canada, the Canadian per capita consumption of fresh potatoes in 2003 was 34.48 kg (McLaughlin 2005). Projecting this figure to the Halifax peninsula population, 2015.9 tonnes of potatoes is needed to satisfy the demand on the peninsula.

4.2. SHADED RELIEF

The following graphs show the frequency distributions of the sizes of sun exposure areas.

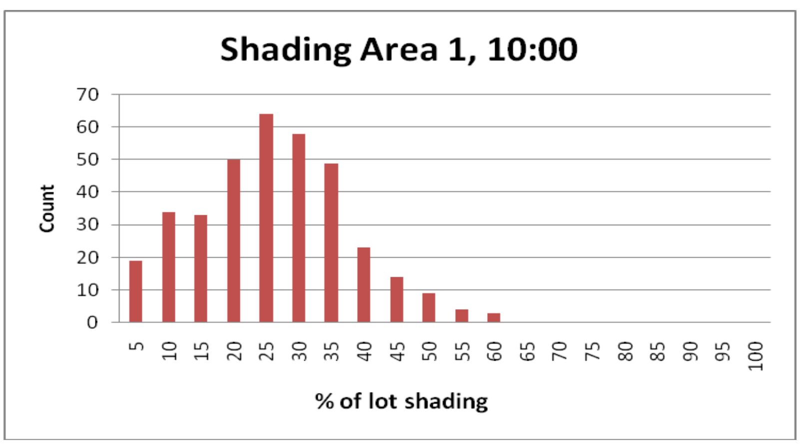

FIGURE 5. PERCENT OF LOT SHADED AT 10:00, AREA 1

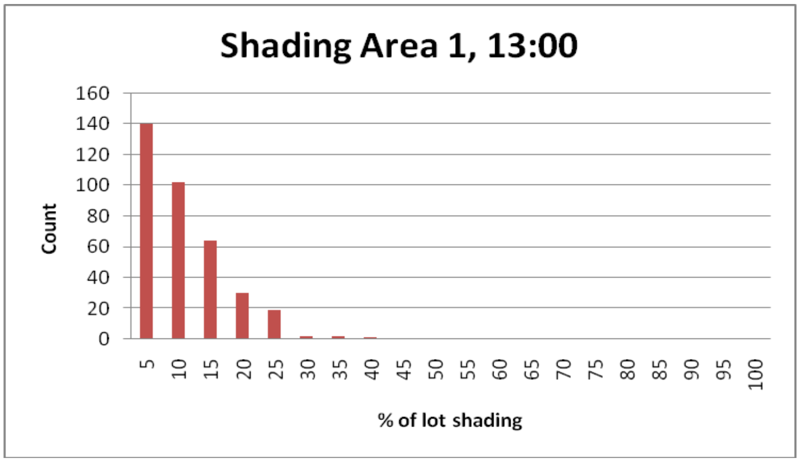

FIGURE 6. PERCENT OF LOT SHADED AT 13:00, AREA 1

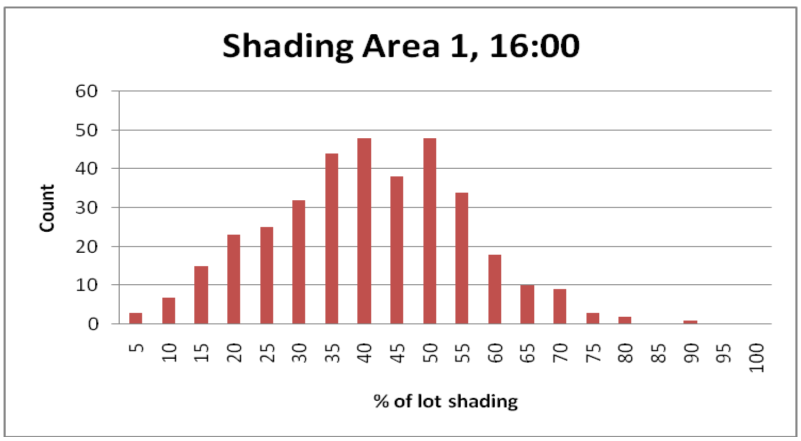

FIGURE 7. PERCENT OF LOT SHADED AT 16:00, AREA 1

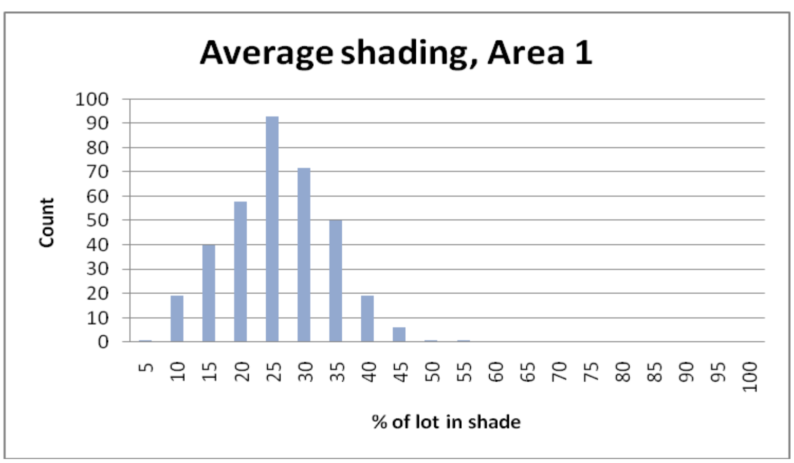

FIGURE 8. AVERGAE PERCENT OF LOT IN SHADE, AREA 1

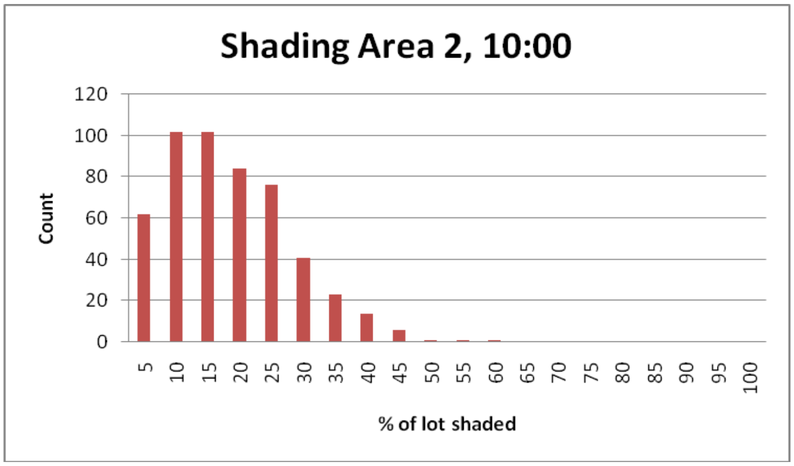

FIGURE 9. PERCENT OF LOT SHADED AT 10:00, AREA 2

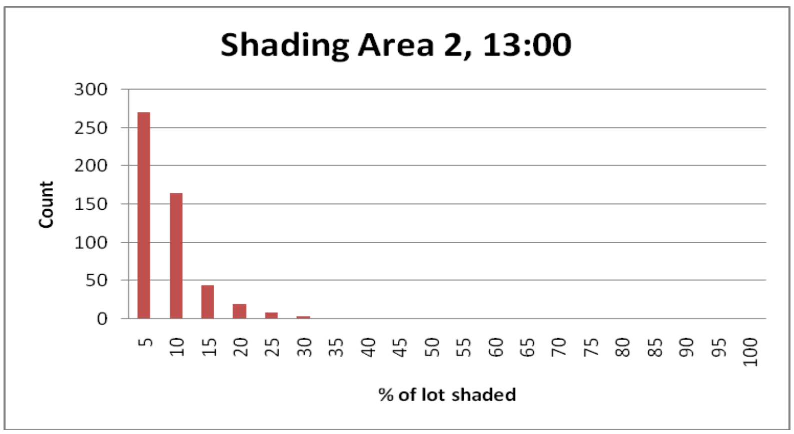

FIGURE 10. PERCENT OF LOT SHADED AT 13:00, AREA 2

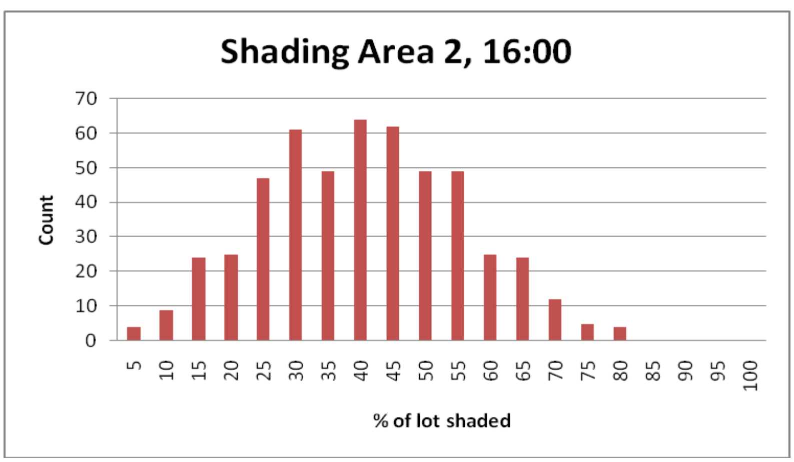

FIGURE 11. PERCENT OF LOT SHADED AT 16:00, AREA 2

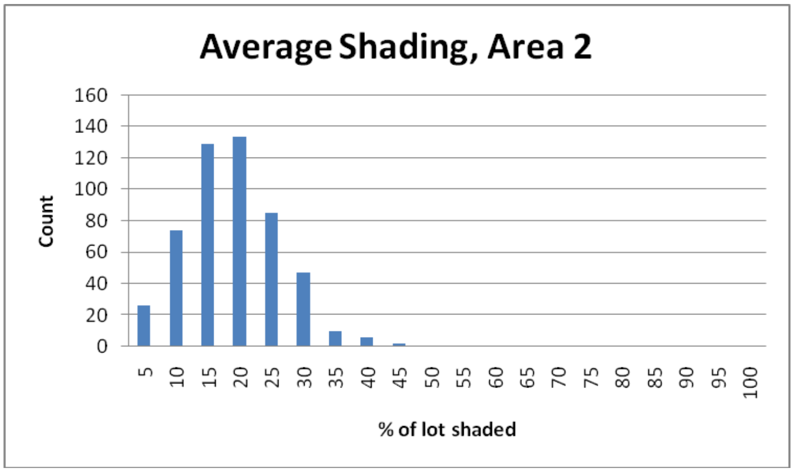

FIGURE 12. AVERAGE PERCENT OF LOT IN SHADE, AREA 2

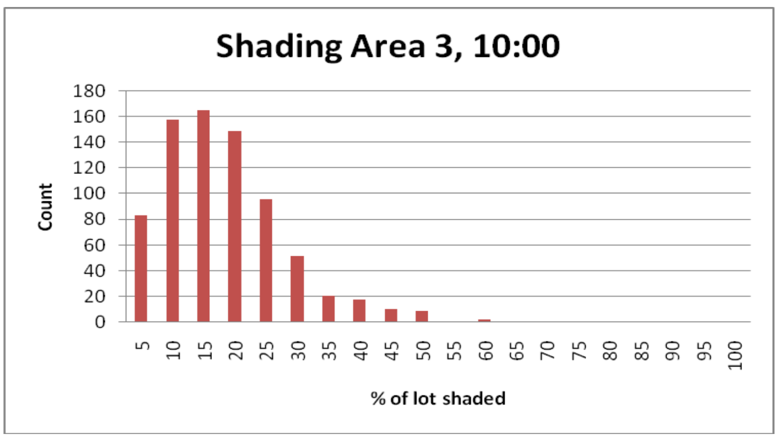

FIGURE 13 PERCENT OF LOT SHADED AT 10:00, AREA 3

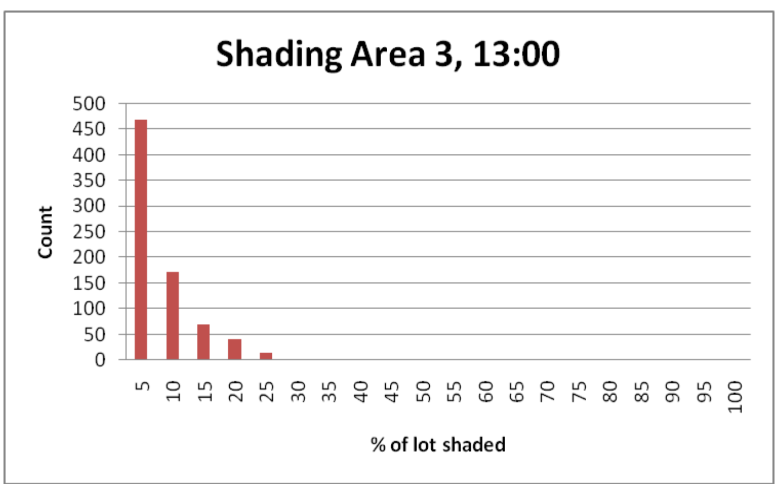

FIGURE 14. PERCENT OF LOT SHADED AT 13:00, AREA 3

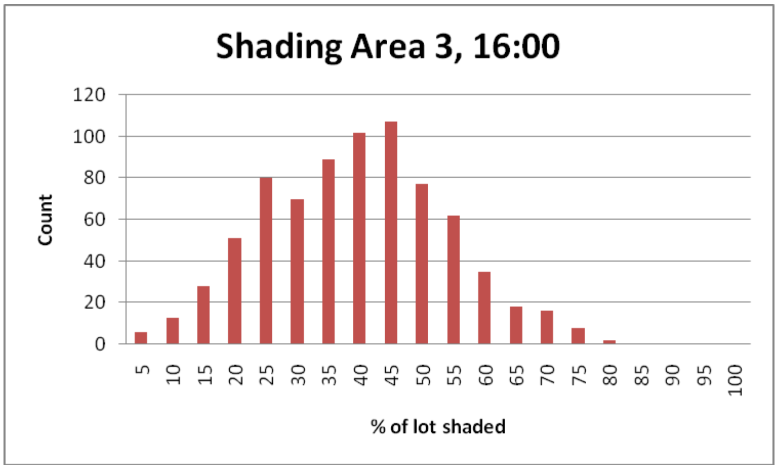

FIGURE 15. PERCENT OF LOT SHADED AT 16:00, AREA 3

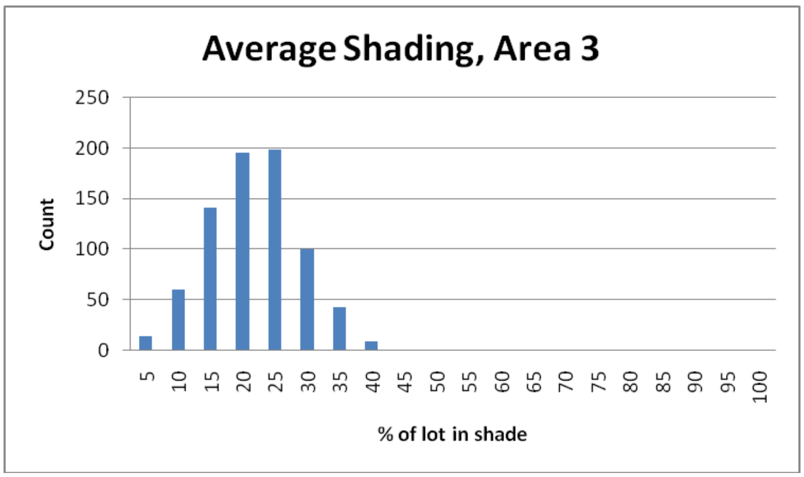

FIGURE 16. AVERAGE PERCENT OF LOT IN SHADE, AREA 3

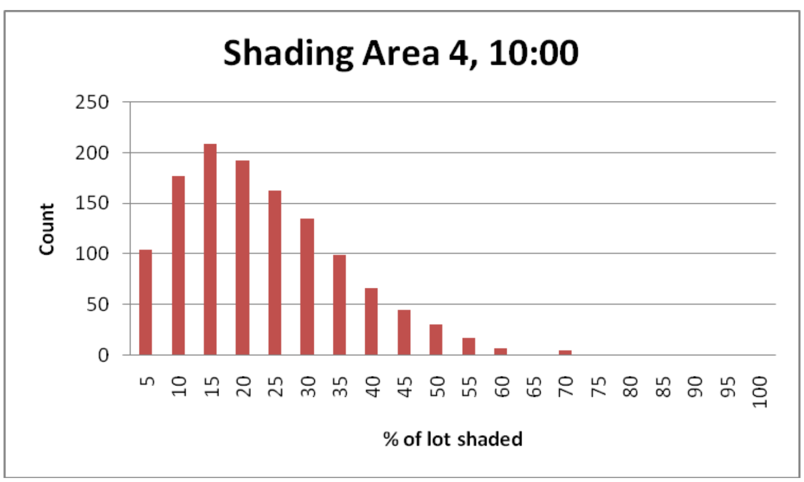

FIGURE 17. PERCENT OF LOT SHADED AT 10:00, AREA 4

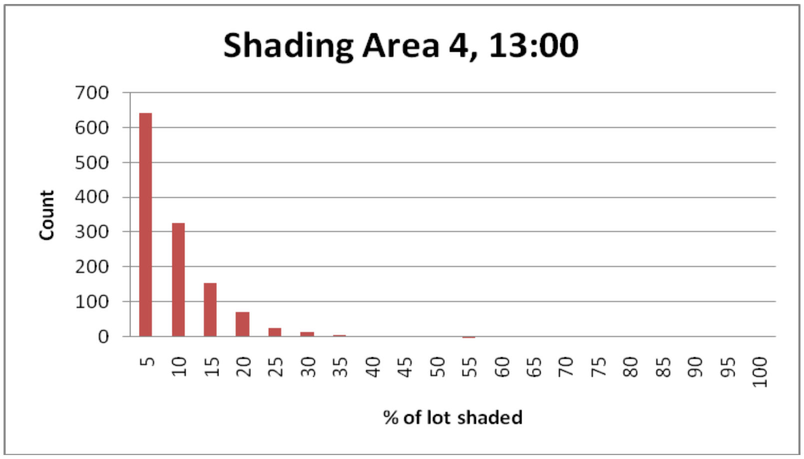

FIGURE 18. PERCENT OF LOT SHADED AT 13:00, AREA 4

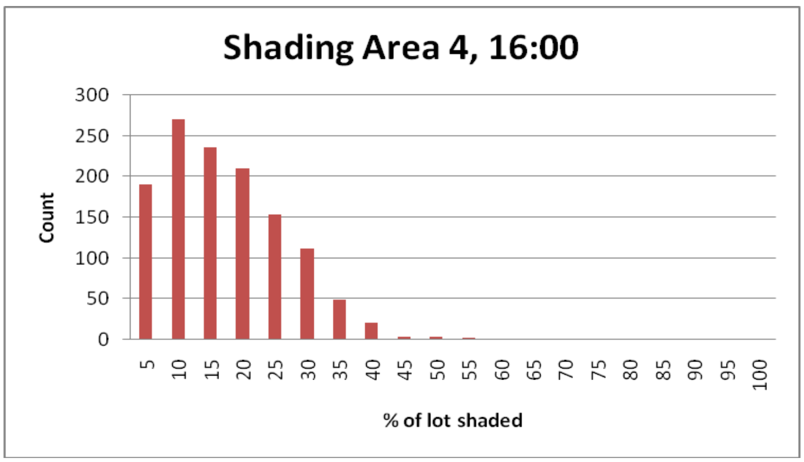

FIGURE 19. PERCENT OF LOT SHADED AT 16:00, AREA 4

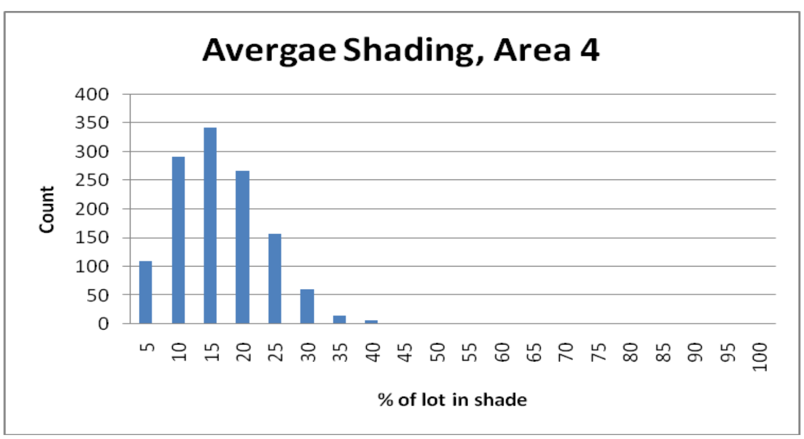

FIGURE 20. AVERAGE PERCENT OF LOT IN SHADE, AREA 4

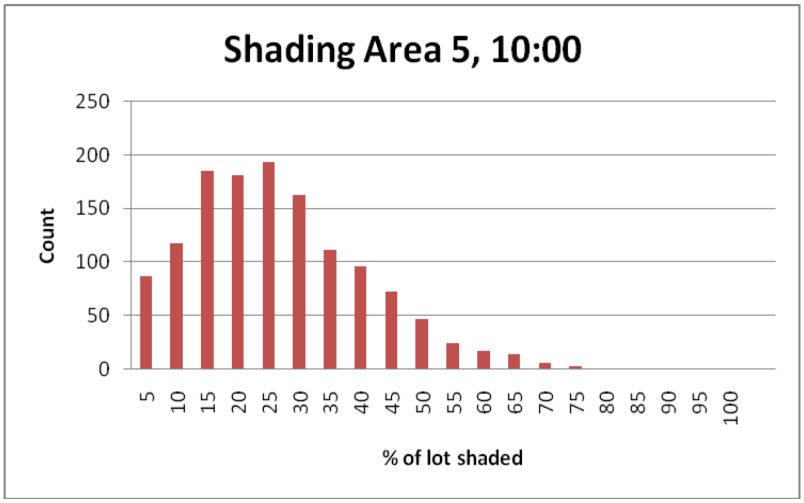

FIGURE 21. PERCENT OF LOT SHADED AT 10:00, AREA 5

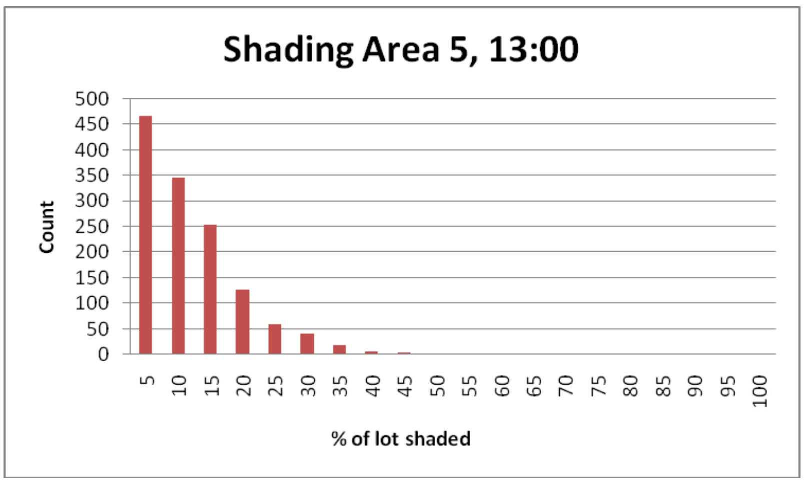

FIGURE 22. PERCENT OF LOT SHADED AT 13:00, AREA 5

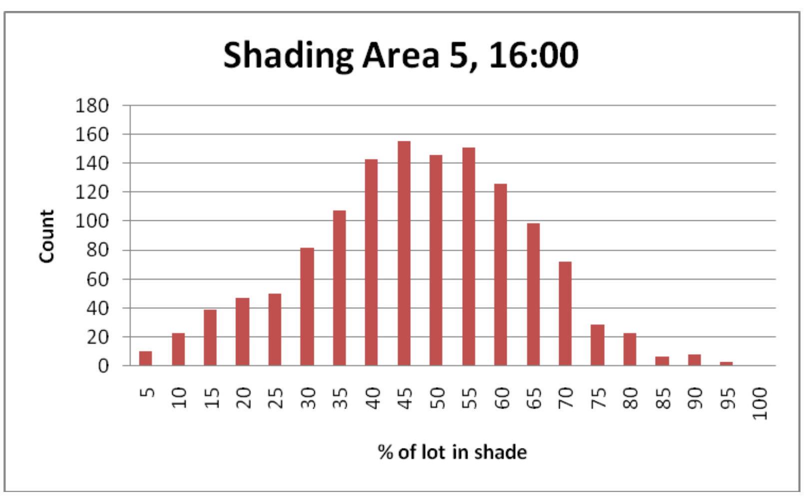

FIGURE 23. PERCENT OF LOT SHADED AT 16:00, AREA 5

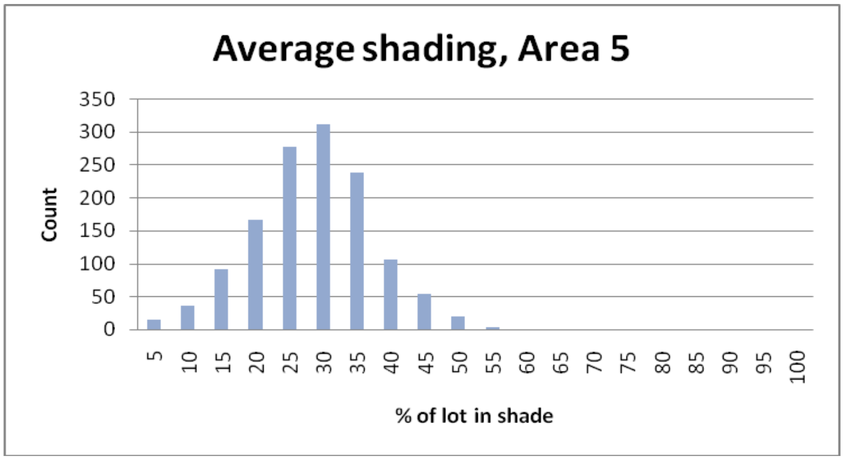

FIGURE 24. AVERAGE PERCENT OF LOT IN SHADE, AREA 5

TABLE 2 AVERAGE PERCENT OF LOT SHADED

time	Area 1	Area 2	Area 3	Area 4	Area 5
10:00	23.5	15.9	15.7	20.5	24.1
13:00	8.2	5.6	5.1	6.5	9.4
16:00	38.2	38.1	37.0	37.0	44.7

5. ANALYSIS

Measuring the total available potential space for urban agriculture in an urban setting may be difficult since available areas are disconnected, and the entirety of available space underestimated. After erasing obstructing features from a map of yards, it was determined that 3.2 km^2 of the 20 km^2 peninsula are yards which could potentially be used for urban agriculture, given that other factors are suitable for urban agriculture. By projecting yield factors, over 7 million kg of potatoes or 1 million kg of lettuce could be produced annually. For the Halifax peninsula population of 58,466, 2 million kg of potatoes and 646 000 kg of lettuce would be needed per year. According to these figures, the peninsula could grow enough potatoes and lettuce to satisfy this demand, however, these are just two crops on the long list of crops consumed. Considering that the potato and lettuce demand on the peninsula would require around 2.5 km^2, the peninsula would not be able to satisfy the total vegetable demand on the peninsula. Furthermore, the winter demand cannot be met. It is not suggested that urban agriculture should displace fruits and vegetables from Maritime farms, but rather, local food, including food grown and produced in the Maritimes and within urban areas, should have a stronger prevalence in the food system. However, an increased dependence on crops grown in the urban setting reduces negative effects of imported crops, as discussed previously. The results show that a large amount of vegetables can be produced, where conditions are suitable.

The sun exposure examinations revealed the portion of the yards in shade. The frequency distribution graphs indicate that for the majority of the yards, a large portion receives sunlight. All yards showed similar frequency distributions. At all sites, there was little shading at 13:00, with most of the shading occurring at 16:00. Overall, very few yards showed 100% shade, even in the late afternoon. No yards showed 100% shading during the whole day. Since sunlight was received at least at one of those three times, crops that require little sun can be grown here. The average shading was 21%, and none of the areas had more than 50% shading during the three observed times. Despite limitations and delimitations, the results indicate that shading does not severely limit agriculture on the peninsula, and crops grown in these yards would receive the required amount of sunlight during the summer.

Incorporating shading trends into the prediction of total potential yard space reduced the area by 0.8 km^2, leaving 3.2 km^2 of yard space. All yards receive sunlight at midday, a vital time for sun exposure, since the sun is strongest at this time. At this time, all yards had low levels of shading, averages ranging between 5.1% and 9.4% yard shading. Although there is higher amounts of shading during the afternoon, averages ranging from 37% to 44.7% shading, the low levels of shading during the late morning (averages between 15.7% and 24.1%), indicate that the yards with high amounts of shading during the late afternoon likely have low levels of shading during the morning and midday, and can therefore be suitable habitats for cultivation of moderately shade tolerant crops. Successful gardening requires careful allotment, and observation of shading trends is necessary. Vegetables requiring moderate amounts of sunlight can be planted in areas that receive sunlight at midday and during the morning and/or late afternoon.

6. LIMITATIONS, RECOMMENDATIONS, CONCLUSIONS

An examination of the potential space revealed that 3.2 km^2, or 1/6 of the peninsula is yards. This space is unobstructed by buildings and roads, and may be potential areas for cultivation of crops. Shade relief models showed that shading in the summer covers on average between 0 and 55% of the yard space. Therefore, it is concluded that there is enough land available to produce on the Halifax peninsula a significant fraction of the summer-season vegetables consumed there. It is recognised that there are limiting physical factors of urban agriculture specific to each yard, however, with the gardener's effort, these limitations can be overcome. There are innovative techniques which allow initially unsuitable areas to be productive cornucopias. Inaccessibility to these techniques should not be a limiting factor for urban agriculture. Further efforts should be directed at creating a centralised, accessible resource for Haligonians interested in urban agriculture. Solutions for other limitations of urban agriculture should be explored and made available for current and potential urban farmers. Bylaws and regulations should not hinder urban agriculture.

Although individual parcels of land may be small, food production may still occur at these locations. Studies show that smaller farming plots have a higher yield per hectare than large-scale farms. (Rosset 2000) The productivity per unit area of a land is not limited by the total size it encompasses. The potential productivity of a yard also depends on the gardener. Although 1 m^2 can be used for growing crops, the resident may not find this worth the effort of establishing and maintaining a garden.

Urban planners should include urban agriculture in design, and consider factors that promote urban agriculture. Space should be allocated for community gardens, and considerations should be made to reserve land that is suitable for urban agriculture. New developments should include space for agriculture, whether through the structural integrity of green roofs, by placing balconies in south facing directions, or by allocating yard space in areas that are well lit with good soil. This study did not consider public areas such as parks and fields, or idle lands, areas that are underused or abandoned. There may be great potential for agriculture in these areas as well. Halifax has islands of available space that can be utilised for cultivation, which, in entirety, encompasses a large area.

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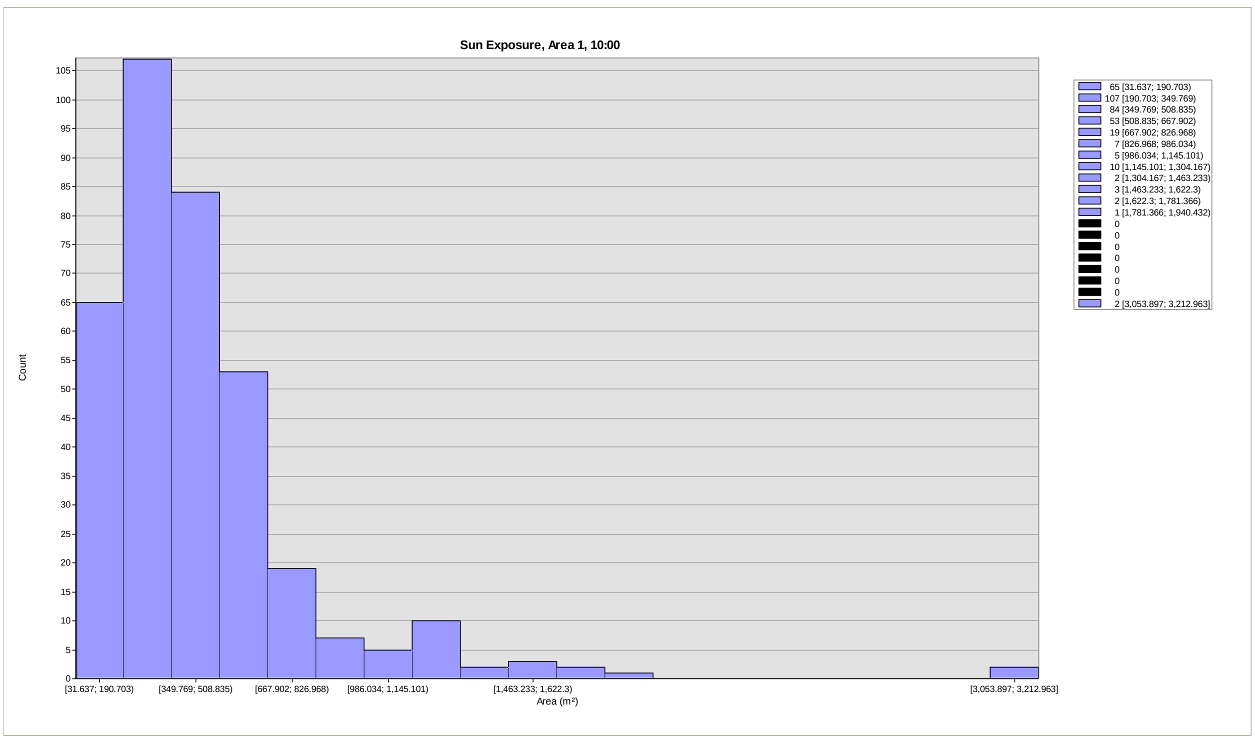
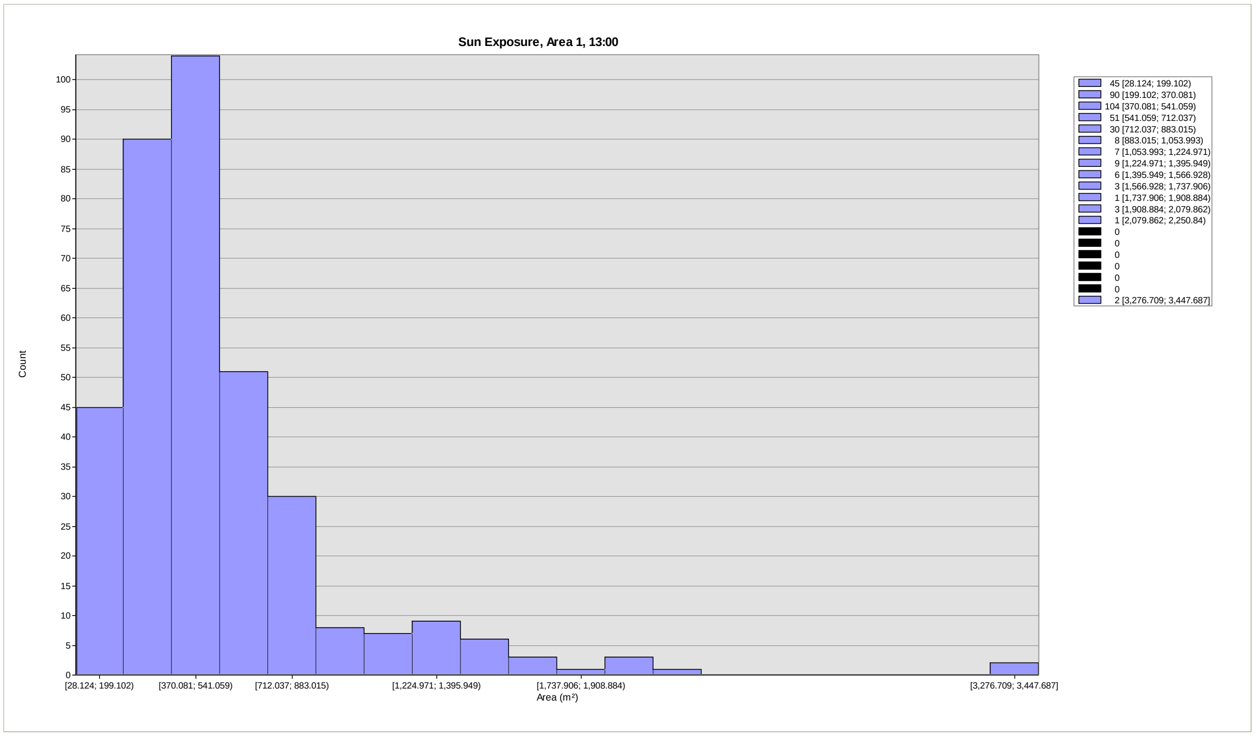
8. APPENDIX

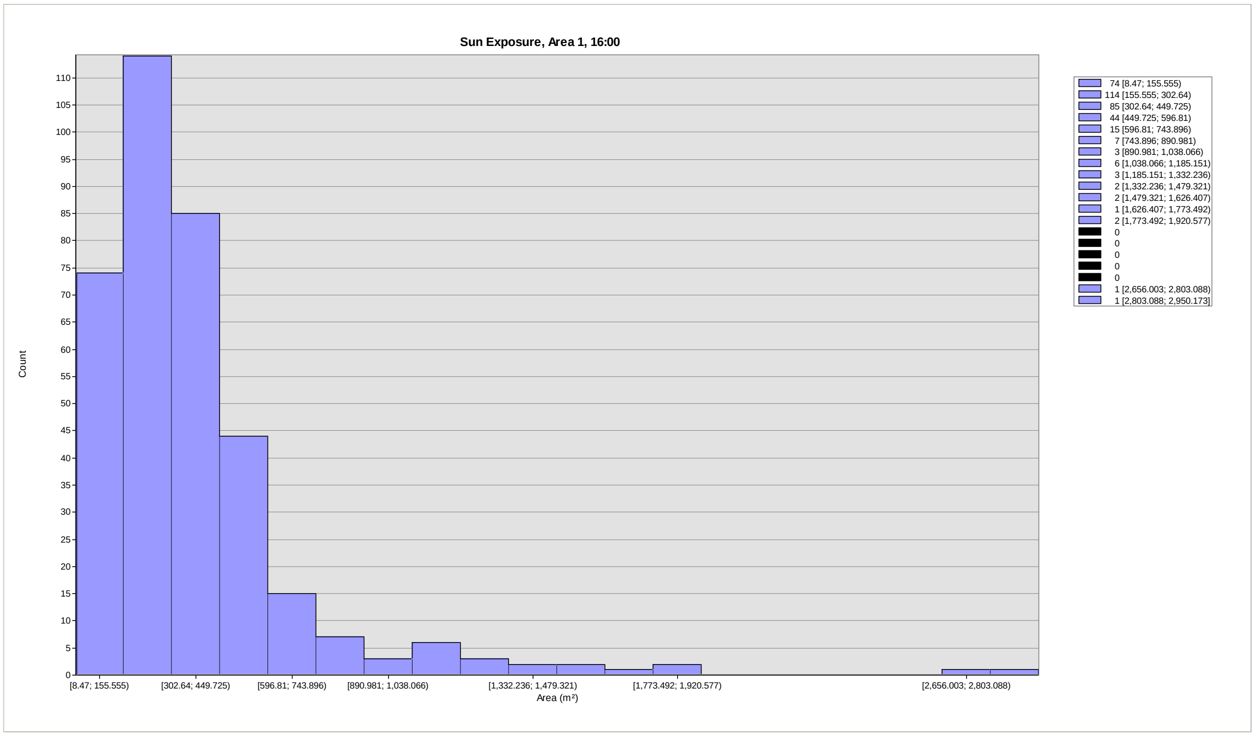
HISTOGRAMS OF YARD SIZES EXPOSED TO SUN

The following histograms display the size of yards receiving sunlight at given times. The graphs were created in ArcMap from the attribute tables. This information, in conjunction with original yard sizes, was used to create histograms of portions of yards in shade.

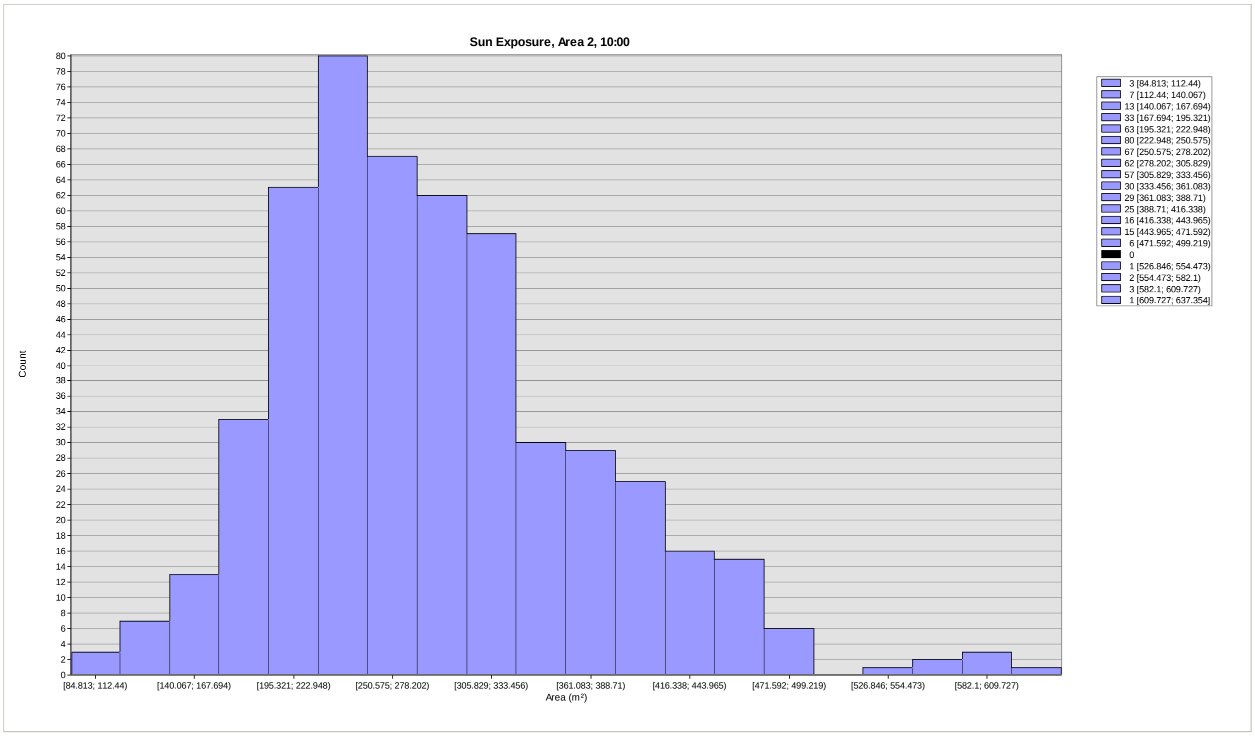




Sun Exposure, Area 1, 13:00
Count
Area (m²)
[28.124; 199.102)
[370.081; 541.059)
[712.037; 883.015)
[1,224.971; 1,395.949)
[1,737.906; 1,908.884)
[3,276.709; 3,447.687]
45 [28.124; 199.102)
90 [199.102; 370.081)
104 [370.081; 541.059)
51 [541.059; 712.037)
30 [712.037; 883.015)
8 [883.015; 1,053.993)
7 [1,053.993; 1,224.971)
9 [1,224.971; 1,395.949)
6 [1,395.949; 1,566.928)
3 [1,566.928; 1,737.906)
1 [1,737.906; 1,908.884)
3 [1,908.884; 2,079.862)
1 [2,079.862; 2,250.84)
0
0
0
0
0
0
2 [3,276.709; 3,447.687]



Sun Exposure, Area 1, 16:00
Count
Area (m²)
[8.47; 155.555)
[302.64; 449.725)
[596.81; 743.896)
[890.981; 1,038.066)
[1,332.236; 1,479.321)
[1,773.492; 1,920.577)
[2,656.003; 2,803.088)
74 [8.47; 155.555)
114 [155.555; 302.64)
85 [302.64; 449.725)
44 [449.725; 596.81)
15 [596.81; 743.896)
7 [743.896; 890.981)
3 [890.981; 1,038.066)
6 [1,038.066; 1,185.151)
3 [1,185.151; 1,332.236)
2 [1,332.236; 1,479.321)
2 [1,479.321; 1,626.407)
1 [1,626.407; 1,773.492)
2 [1,773.492; 1,920.577)
0
0
0
0
0
1 [2,656.003; 2,803.088)
1 [2,803.088; 2,950.173]


Sun Exposure, Area 2, 10:00
Count
Area (m²)
[84.813; 112.44)
[140.067; 167.694)
[195.321; 222.948)
[250.575; 278.202)
[305.829; 333.456)
[361.083; 388.71)
[416.338; 443.965)
[471.592; 499.219)
[526.846; 554.473)
[582.1; 609.727)
3 [84.813; 112.44)
7 [112.44; 140.067)
13 [140.067; 167.694)
33 [167.694; 195.321)
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80 [222.948; 250.575)
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25 [388.71; 416.338)
16 [416.338; 443.965)
15 [443.965; 471.592)
6 [471.592; 499.219)
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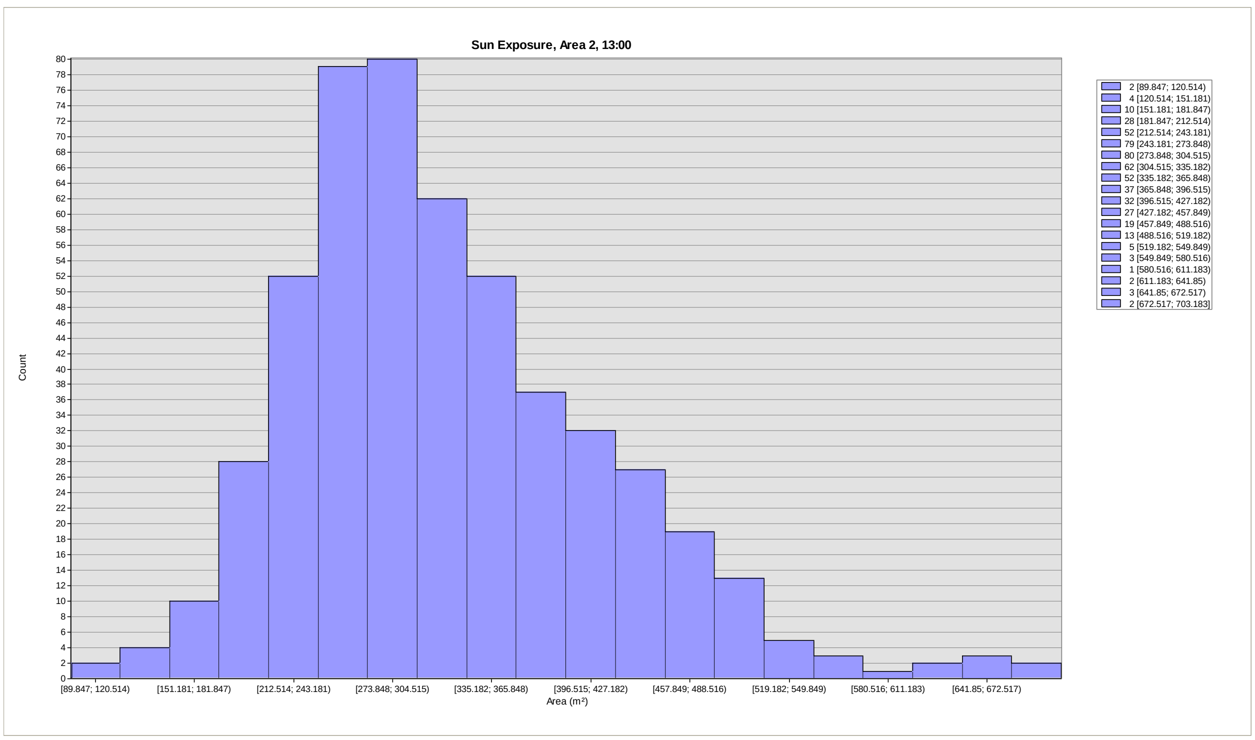
3 [582.1; 609.727)
1 [609.727; 637.354]


Sun Exposure, Area 2, 13:00
Count
Area (m²)
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[151.181; 181.847)
[212.514; 243.181)
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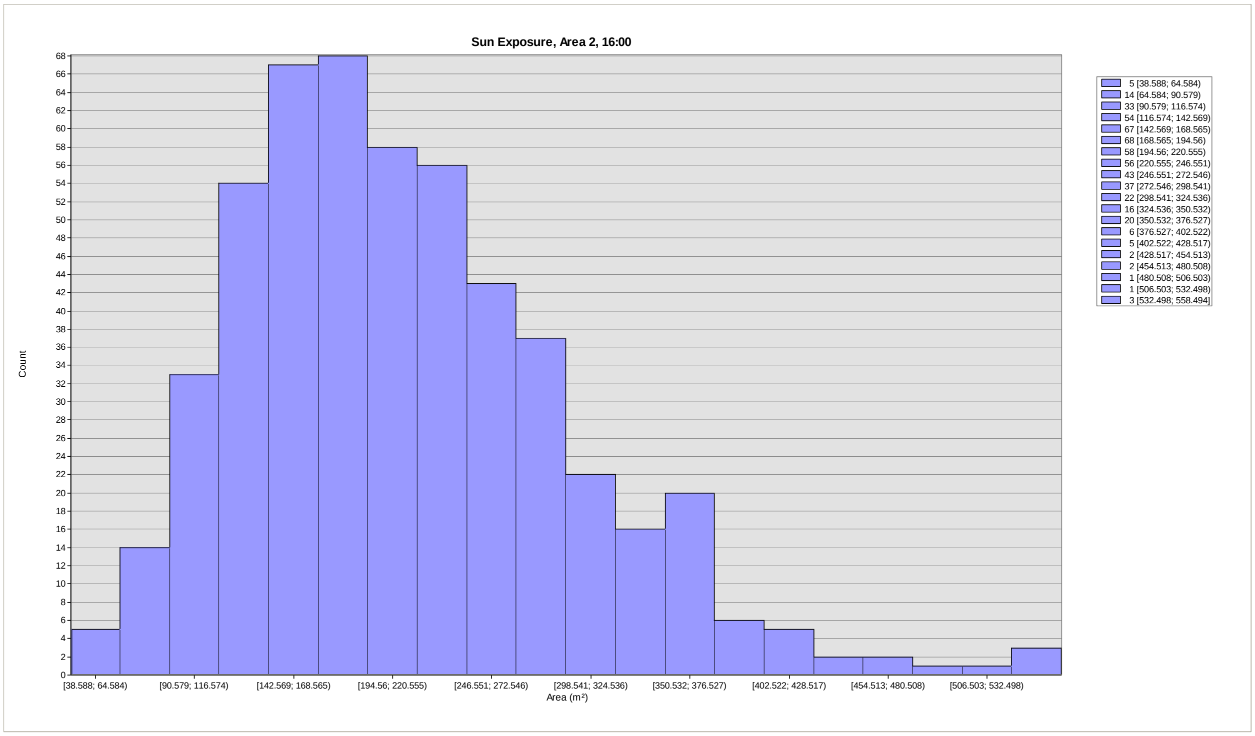
[335.182; 365.848)
[396.515; 427.182)
[457.849; 488.516)
[519.182; 549.849)
[580.516; 611.183)
[641.85; 672.517)
2 [89.847; 120.514)
4 [120.514; 151.181)
10 [151.181; 181.847)
28 [181.847; 212.514)
52 [212.514; 243.181)
79 [243.181; 273.848)
80 [273.848; 304.515)
62 [304.515; 335.182)
52 [335.182; 365.848)
37 [365.848; 396.515)
32 [396.515; 427.182)
27 [427.182; 457.849)
19 [457.849; 488.516)
13 [488.516; 519.182)
5 [519.182; 549.849)
3 [549.849; 580.516)
1 [580.516; 611.183)
2 [611.183; 641.85)
3 [641.85; 672.517)
2 [672.517; 703.183]


Sun Exposure, Area 2, 16:00
Count
Area (m²)
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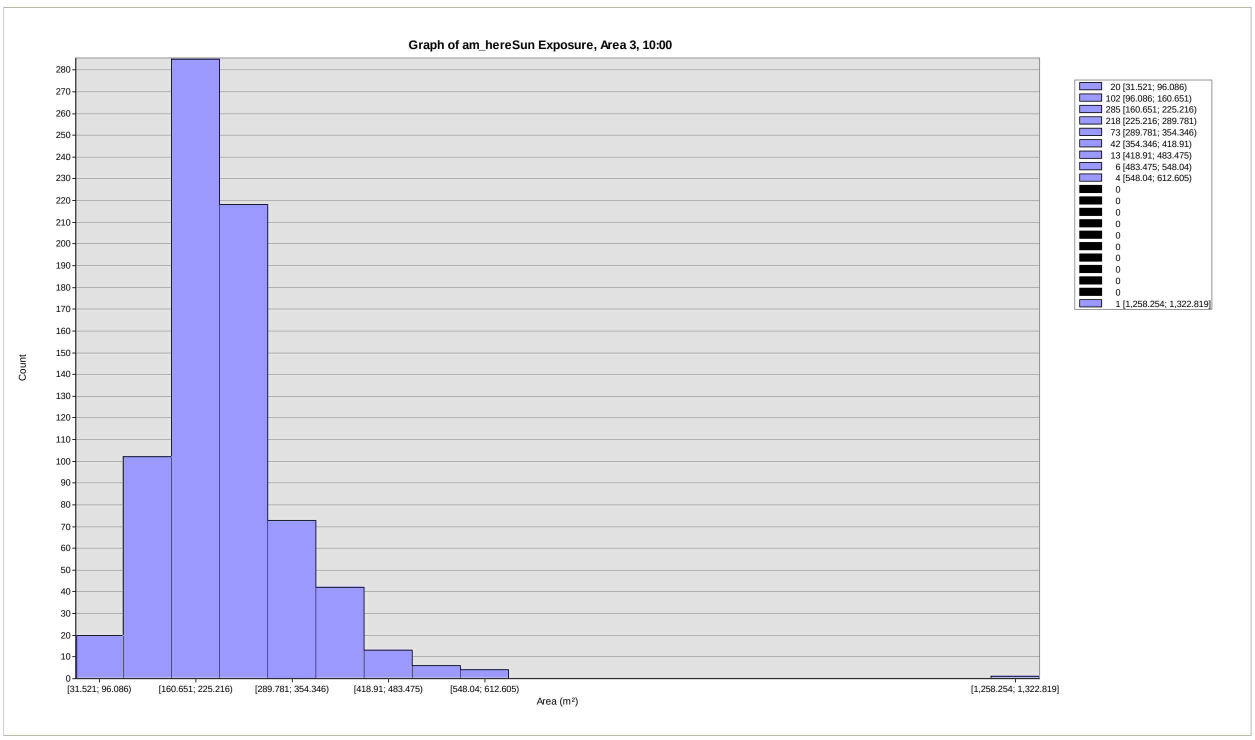
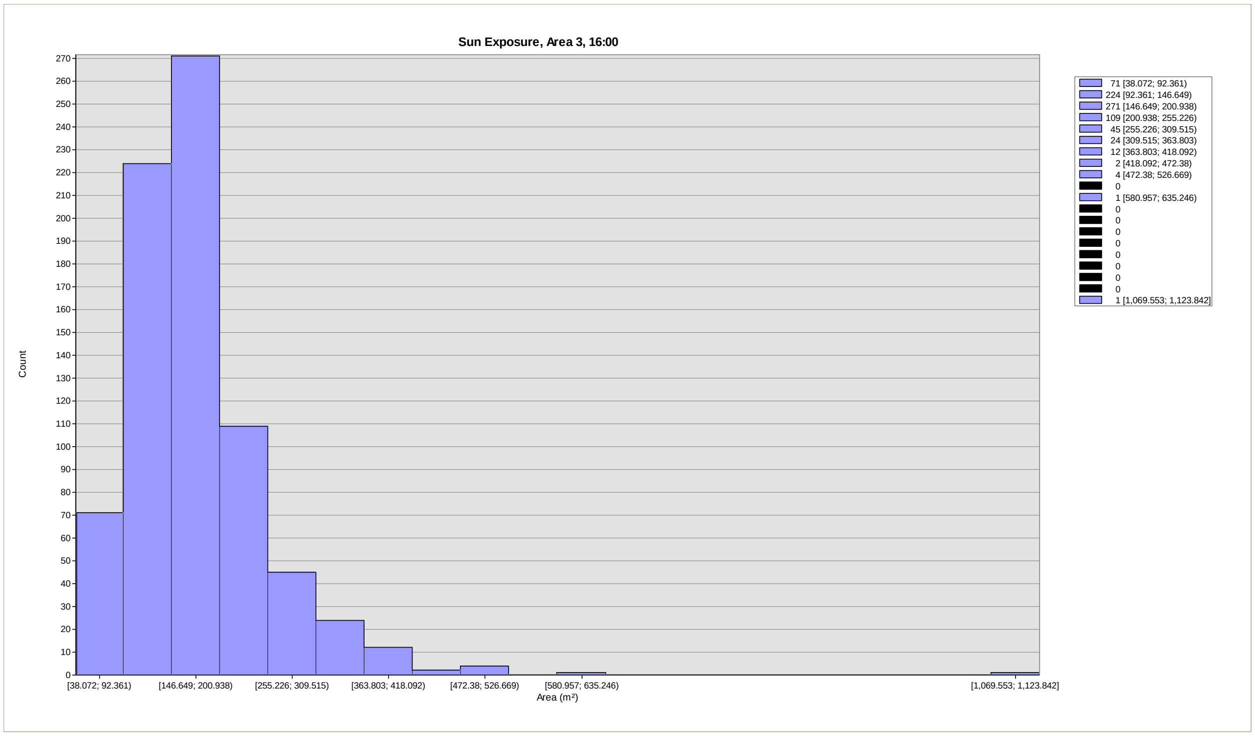
[142.569; 168.565)
[194.56; 220.555)
[246.551; 272.546)
[298.541; 324.536)
[350.532; 376.527)
[402.522; 428.517)
[454.513; 480.508)
[506.503; 532.498)
5 [38.588; 64.584)
14 [64.584; 90.579)
33 [90.579; 116.574)
54 [116.574; 142.569)
67 [142.569; 168.565)
68 [168.565; 194.56)
58 [194.56; 220.555)
56 [220.555; 246.551)
43 [246.551; 272.546)
37 [272.546; 298.541)
22 [298.541; 324.536)
16 [324.536; 350.532)
20 [350.532; 376.527)
6 [376.527; 402.522)
5 [402.522; 428.517)
2 [428.517; 454.513)
2 [454.513; 480.508)
1 [480.508; 506.503)
1 [506.503; 532.498)
3 [532.498; 558.494]


Graph of am_hereSun Exposure, Area 3, 10:00
Count
Area (m²)
[31.521; 96.086)
[160.651; 225.216)
[289.781; 354.346)
[418.91; 483.475)
[548.04; 612.605)
[1,258.254; 1,322.819]
20 [31.521; 96.086)
102 [96.086; 160.651)
285 [160.651; 225.216)
218 [225.216; 289.781)
73 [289.781; 354.346)
42 [354.346; 418.91)
13 [418.91; 483.475)
6 [483.475; 548.04)
4 [548.04; 612.605)
0
0
0
0
0
0
0
0
0
0
1 [1,258.254; 1,322.819]


Sun Exposure, Area 3, 16:00
Count
Area (m²)
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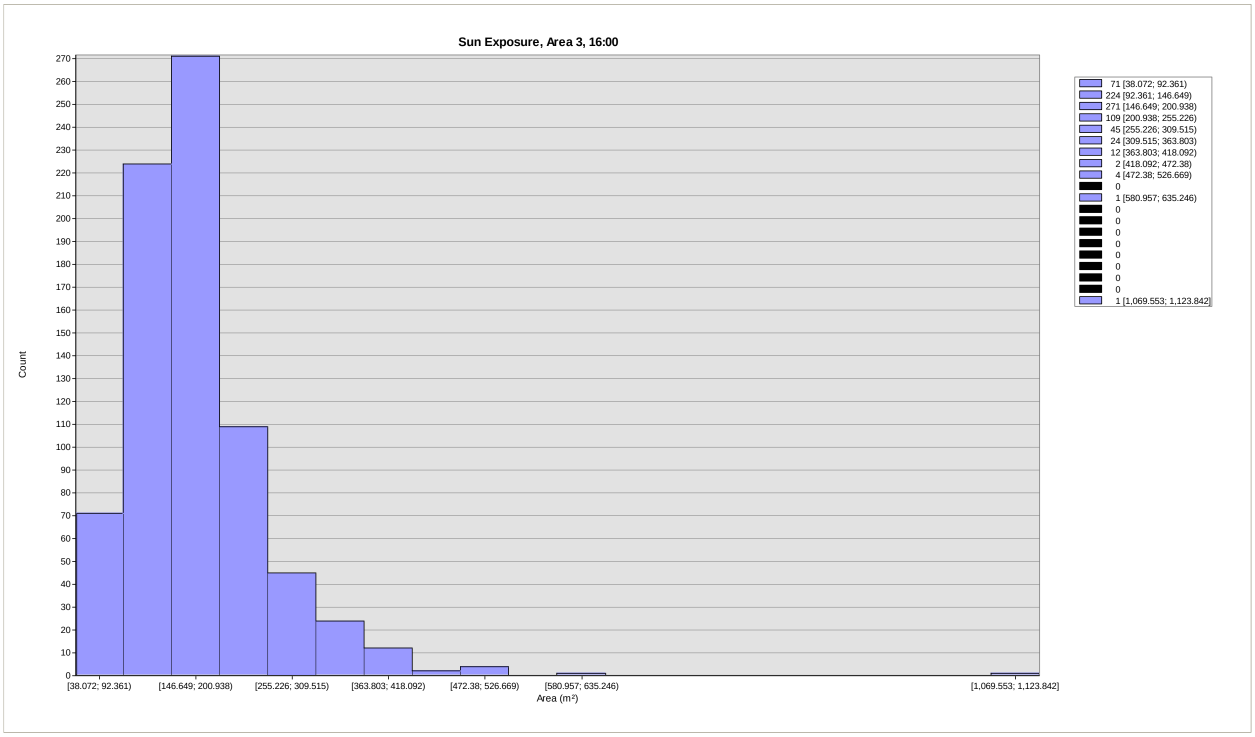
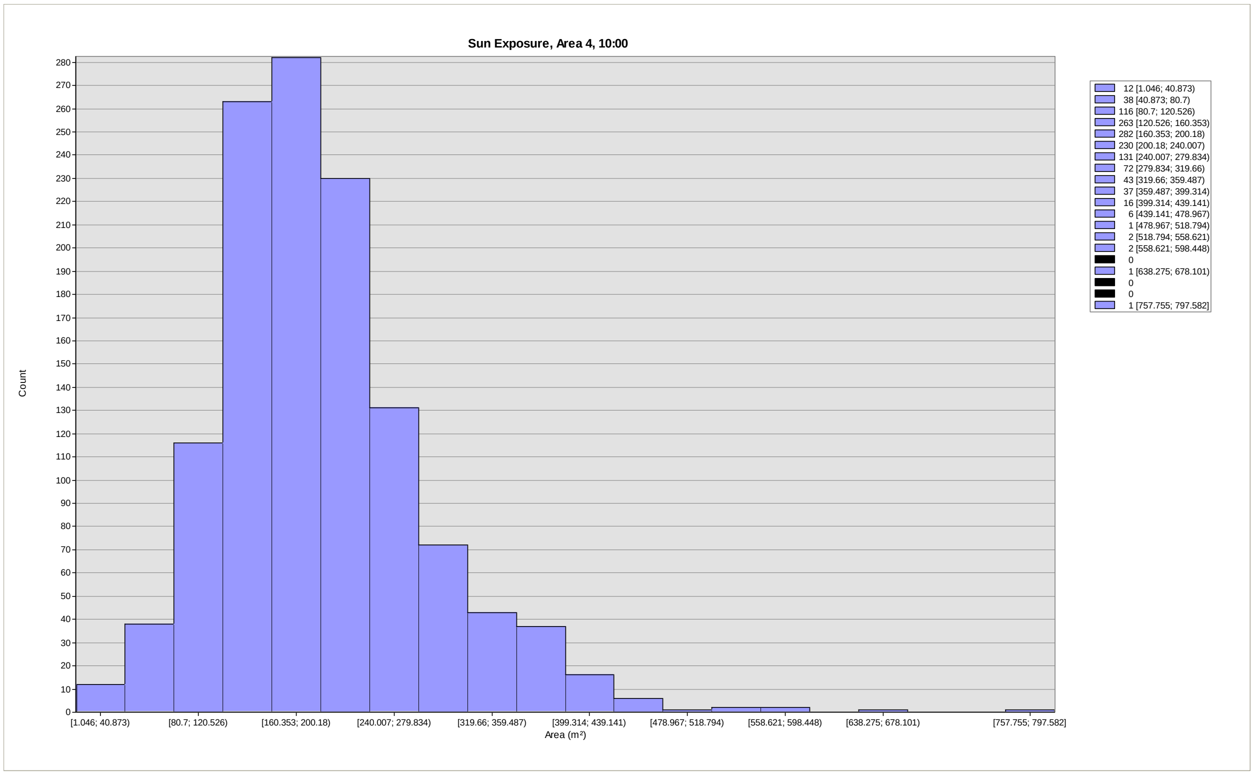
[146.649; 200.938)
[255.226; 309.515)
[363.803; 418.092)
[472.38; 526.669)
[580.957; 635.246)
[1,069.553; 1,123.842]
71 [38.072; 92.361)
224 [92.361; 146.649)
271 [146.649; 200.938)
109 [200.938; 255.226)
45 [255.226; 309.515)
24 [309.515; 363.803)
12 [363.803; 418.092)
2 [418.092; 472.38)
4 [472.38; 526.669)
0
1 [580.957; 635.246)
0
0
0
0
0
0
0
0
1 [1,069.553; 1,123.842]


Sun Exposure, Area 3, 16:00
Count
Area (m²)
[38.072; 92.361)
[146.649; 200.938)
[255.226; 309.515)
[363.803; 418.092)
[472.38; 526.669)
[580.957; 635.246)
[1,069.553; 1,123.842]
71 [38.072; 92.361)
224 [92.361; 146.649)
271 [146.649; 200.938)
109 [200.938; 255.226)
45 [255.226; 309.515)
24 [309.515; 363.803)
12 [363.803; 418.092)
2 [418.092; 472.38)
4 [472.38; 526.669)
0
1 [580.957; 635.246)
0
0
0
0
0
0
0
0
1 [1,069.553; 1,123.842]


Sun Exposure, Area 4, 10:00
Count
Area (m²)
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38 [40.873; 80.7)
116 [80.7; 120.526)
263 [120.526; 160.353)
282 [160.353; 200.18)
230 [200.18; 240.007)
131 [240.007; 279.834)
72 [279.834; 319.66)
43 [319.66; 359.487)
37 [359.487; 399.314)
16 [399.314; 439.141)
6 [439.141; 478.967)
1 [478.967; 518.794)
2 [518.794; 558.621)
2 [558.621; 598.448)
0
1 [638.275; 678.101)
0
0
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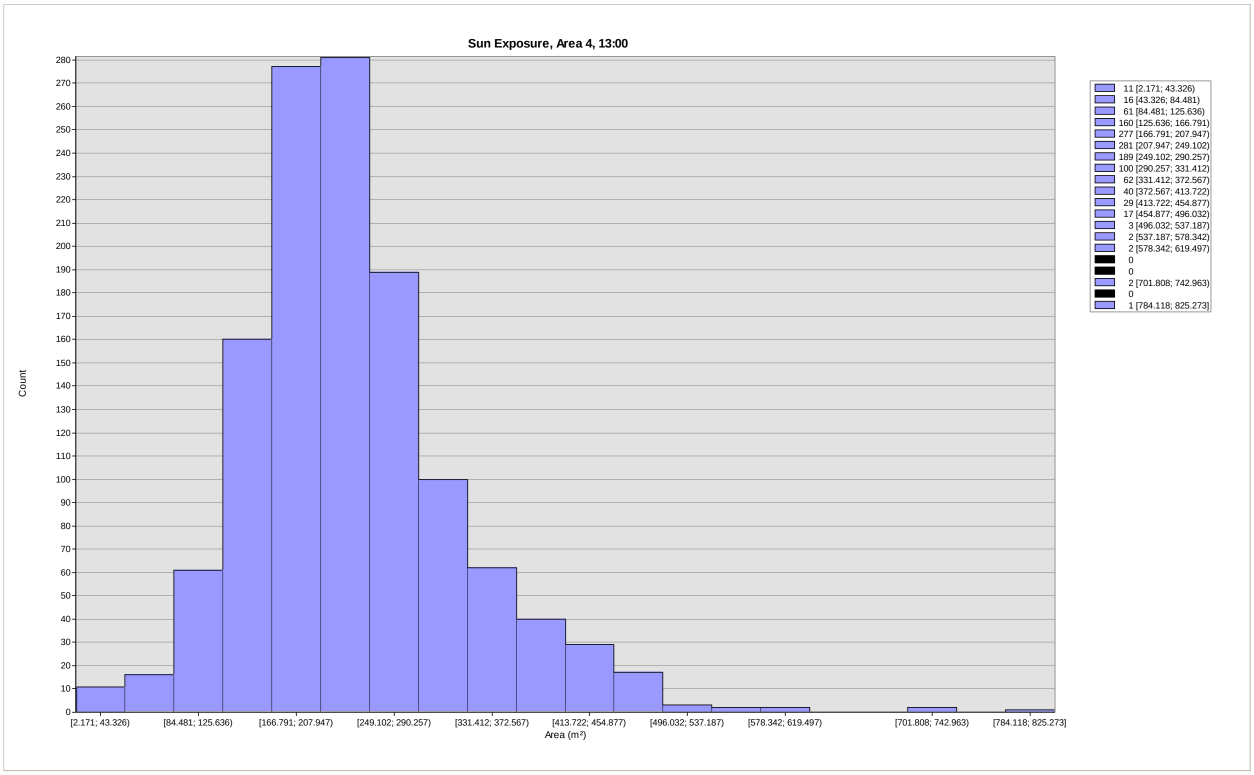
Sun Exposure, Area 4, 13:00
Count
Area (m²)
11 [2.171; 43.326)
16 [43.326; 84.481)
61 [84.481; 125.636)
160 [125.636; 166.791)
277 [166.791; 207.947)
281 [207.947; 249.102)
189 [249.102; 290.257)
100 [290.257; 331.412)
62 [331.412; 372.567)
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29 [413.722; 454.877)
17 [454.877; 496.032)
3 [496.032; 537.187)
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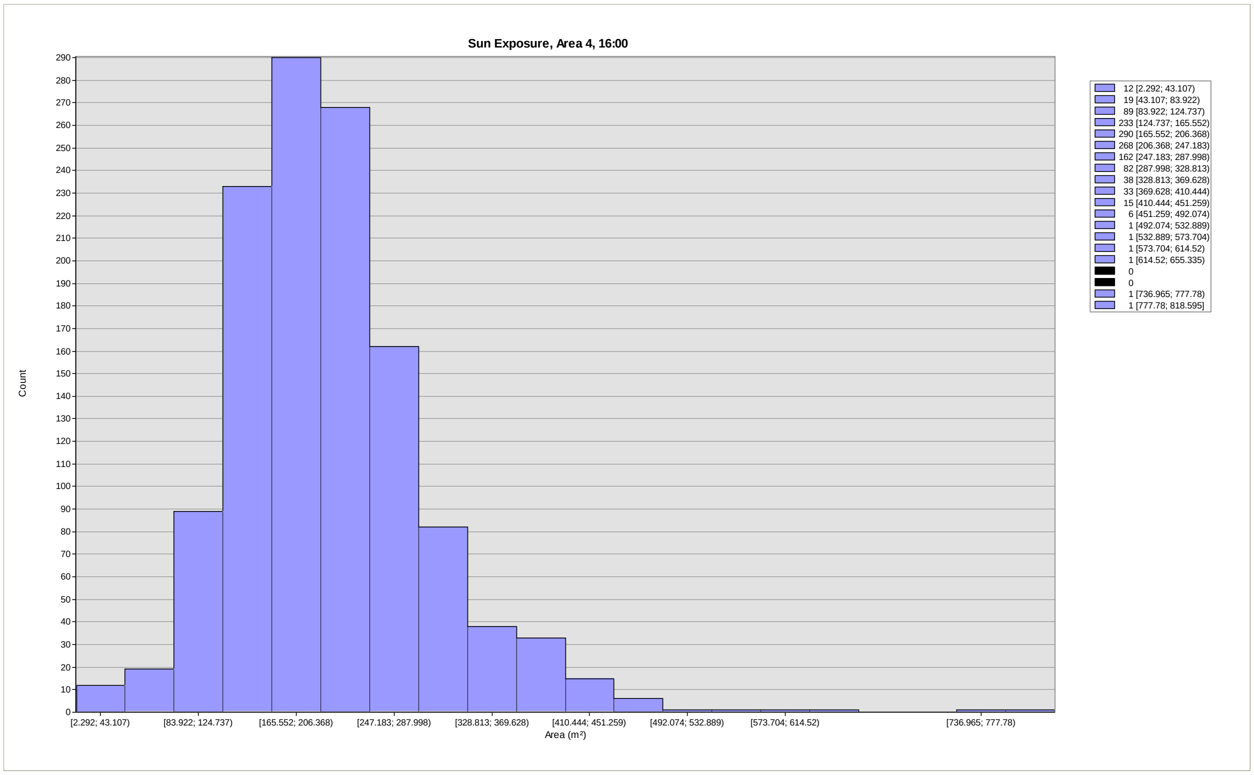
2 [578.342; 619.497)
0
0
2 [701.808; 742.963)
0
1 [784.118; 825.273]



Sun Exposure, Area 4, 16:00
Count
Area (m²)
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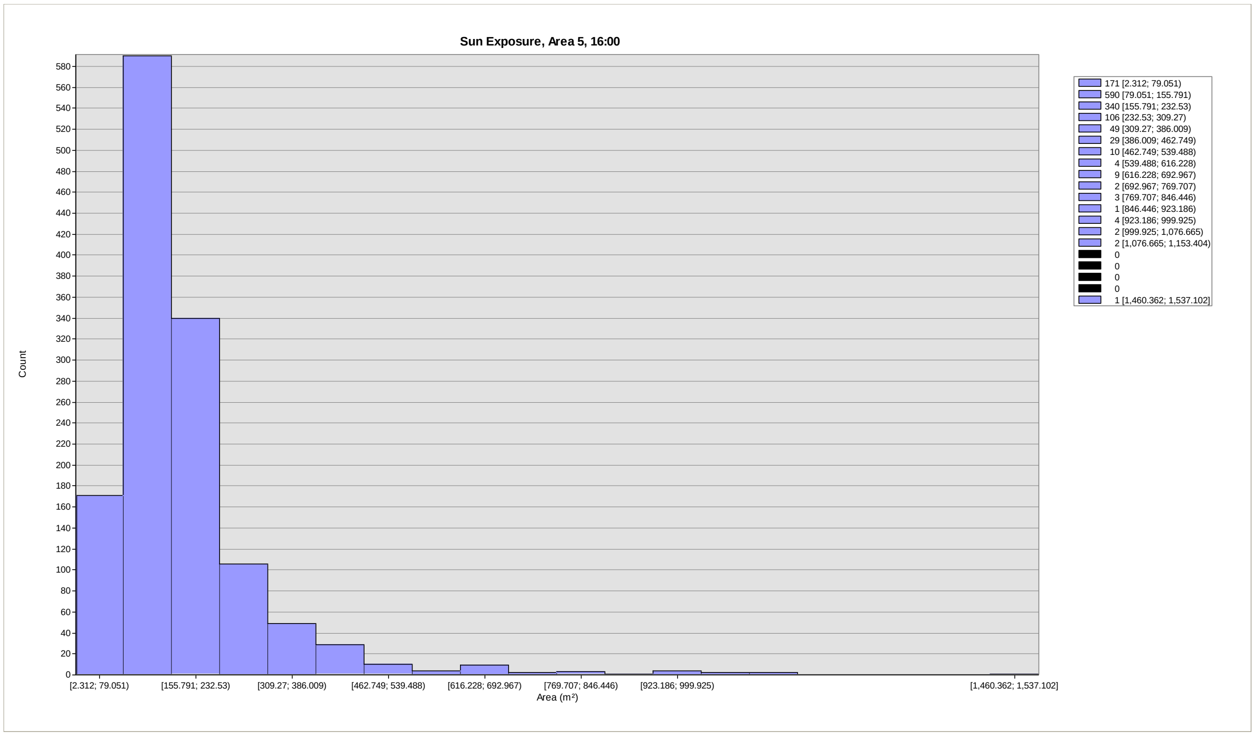
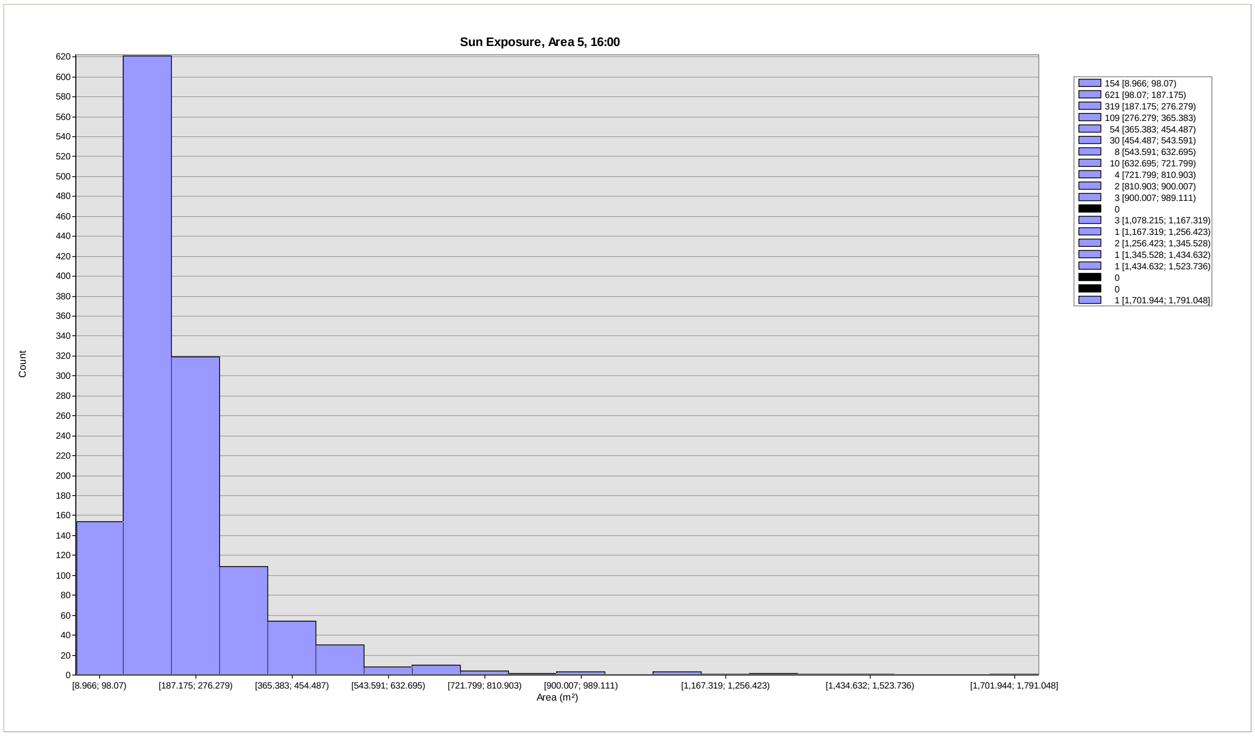
19 [43.107; 83.922)
89 [83.922; 124.737)
233 [124.737; 165.552)
290 [165.552; 206.368)
268 [206.368; 247.183)
162 [247.183; 287.998)
82 [287.998; 328.813)
38 [328.813; 369.628)
33 [369.628; 410.444)
15 [410.444; 451.259)
6 [451.259; 492.074)
1 [492.074; 532.889)
1 [532.889; 573.704)
1 [573.704; 614.52)
1 [614.52; 655.335)
0
0
1 [736.965; 777.78)
1 [777.78; 818.595]



Sun Exposure, Area 5, 16:00
Count
Area (m²)
171 [2.312; 79.051)
590 [79.051; 155.791)
340 [155.791; 232.53)
106 [232.53; 309.27)
49 [309.27; 386.009)
29 [386.009; 462.749)
10 [462.749; 539.488)
4 [539.488; 616.228)
9 [616.228; 692.967)
2 [692.967; 769.707)
3 [769.707; 846.446)
1 [846.446; 923.186)
4 [923.186; 999.925)
2 [999.925; 1,076.665)
2 [1,076.665; 1,153.404)
0
0
0
0
1 [1,460.362; 1,537.102]


Sun Exposure, Area 5, 16:00
Count
Area (m²)
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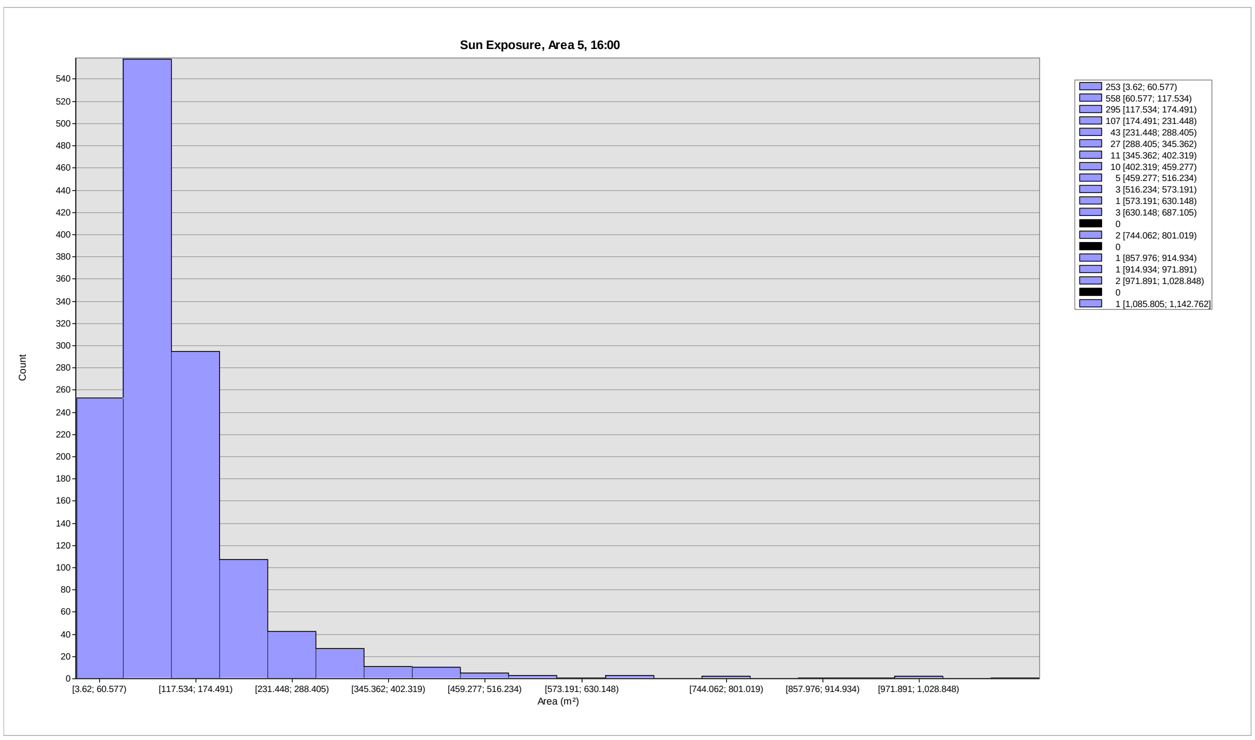
[187.175; 276.279)
[365.383; 454.487)
[543.591; 632.695)
[721.799; 810.903)
[900.007; 989.111)
[1,167.319; 1,256.423)
[1,434.632; 1,523.736)
[1,701.944; 1,791.048]
154 [8.966; 98.07)
621 [98.07; 187.175)
319 [187.175; 276.279)
109 [276.279; 365.383)
54 [365.383; 454.487)
30 [454.487; 543.591)
8 [543.591; 632.695)
10 [632.695; 721.799)
4 [721.799; 810.903)
2 [810.903; 900.007)
3 [900.007; 989.111)
0
3 [1,078.215; 1,167.319)
1 [1,167.319; 1,256.423)
2 [1,256.423; 1,345.528)
1 [1,345.528; 1,434.632)
1 [1,434.632; 1,523.736)
0
0
1 [1,701.944; 1,791.048]


Sun Exposure, Area 5, 16:00
Count
Area (m²)
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[117.534; 174.491)
[231.448; 288.405)
[345.362; 402.319)
[459.277; 516.234)
[573.191; 630.148)
[744.062; 801.019)
[857.976; 914.934)
[971.891; 1,028.848)
253 [3.62; 60.577)
558 [60.577; 117.534)
295 [117.534; 174.491)
107 [174.491; 231.448)
43 [231.448; 288.405)
27 [288.405; 345.362)
11 [345.362; 402.319)
10 [402.319; 459.277)
5 [459.277; 516.234)
3 [516.234; 573.191)
1 [573.191; 630.148)
3 [630.148; 687.105)
0
2 [744.062; 801.019)
0
1 [857.976; 914.934)
1 [914.934; 971.891)
2 [971.891; 1,028.848)
0
1 [1,085.805; 1,142.762]

GIS DATA SOURCES

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Coastline of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Buildings of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Lakes of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Streams of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Streets of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Trees of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Parks of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Property Parcels of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Railroads of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Vegetative Areas of HRM" [ESRI shapefile]. Created by Dalhousie
University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "Recreational Areas of HRM" [ESRI shapefile]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009

Halifax Regional Municipality. Halifax Regional Municipality Corporate Geographic Information System from 2007. "LiDAR data of HRM" [LiDAR data]. Created by Dalhousie University GIS Centre, using ArcInfo 9.3, as a user defined area subset of data. August 2009