Urban agriculture as an integral part of urban growth strategies and the implications on urban form policy-The case of Auckland NZ

[1]Andrew Munya, [2]Hugh Byrd and [3]Errol Haarhoff

[1, 2, 3] The University of Auckland

Department of Architecture and Planning

26 Symonds Street, Auckland NZ

[1]amun265@aucklanduni.ac.nz

[2]h.byrd@aucklanduni.ac.nz

[3] e.haarhoff@aucklanduni.ac.nz

Abstract

Urban agriculture potential is examined in three suburbs of increasing density in Auckland, NZ. A review of the relationship between urban indicators (net density and housing patterns) and potential solar energy available at ground level is done. Since soils are generally fertile and water readily available solar access to ground level becomes an indicator of productivity. Using the subtraction method and satellite photography from Auckland council GIS viewer, potentially productive land is estimated in three residential blocks-Mt Eden, Sandrigham and New Lynn. Based on the results the food energy potential of each site is determined. Preliminary results indicate that low density New Lynn has the highest potential for sustainability with surplus food energy. Medium density Sandrigham could meet 50 per cent of its vegetable dietary requirement while high density Mt Eden is unsustainable in UA. Recommendations are suggested as to how UA maybe integrated in urban growth strategies.

Section 1.00 Introduction

Increasing awareness of urban agriculture and its contribution to city resilience has attracted attention from scholars, researchers, regional and local governments around the world. The result has been initiatives to form policies aimed at promoting UA within the city boundaries by local governments. The focus on the potential for UA has been directed towards urban open spaces, brown fields, community gardens, allotments, vertical spaces, roof gardens etc.

This focus tends to ignore the aim of current urban growth management strategies (UGMS) that promote compact city concept. The aim of the compact city model is to reduce energy consumption costs associated with suburbia by planning housing ,commercial and work facilities within a walking, cycling or public bus/rail radius. Suburbia is perceived by policy makers as the culprit for high transport energy consumption. This policy has ignored the potential that renewable energy, in particular solar energy, can contribute to a city. Solar energy can be used to heat water, be converted to electricity or biomass. However, this all needs a large surface area to collect the sun which favors' suburbia rather than a compact city.

A case in point is the Draft Auckland Plan 2011 whose aim is to make Auckland the world's most livable city. It is projected that by 2040 Auckland's urban population will have increased by one million. This means that an additional 5,000-6,000 hectares of green fields will be needed to for new residential and employment .To accommodate these new developments the plan proposes a new Rural Urban Boundary (RUB) which will contain the new green fields. Concentrating all the development within the RUB means increasing density. To achieve this goal the plan proposes a growth strategy based on urban intensification by concentrating more compact intensive residential centered on beautiful local neighborhoods and centers. For future development, the development strategy introduces the concept of 'development areas'. These are areas that will be based around town centers and corridors but also include suburban areas contiguous to the town centers (Council 2011).

By failing to view UA within the realm of current growth management strategies both UA policy and UGMS inadvertently fail to appreciate the following issues 1) the future competition between UA and other land uses, 2) The scarcity of land for UA (3) the role of suburbia with the larger scheme of the growth machine ((Haarhof & Beattie, 2011) quoting (Hayden, 2002) (4) solar energy potential for UA within suburbia.

Consequently the overall doctoral research focuses on all the four issues. This study forms part one of the research and will focus on examining the availability of potential land for urban agriculture within suburbia and the role of suburbia in UA. These two issues form the basis of discussing the fourth issue-solar access to ground level as indicator of productivity

This paper analyzes the potential for urban agriculture in three suburbs of increasing density in Auckland City.It is assumed that food production is from the ground up and includes only vegetables. The case studies include Mt.Eden, New Lynn and Sandrigham.

1.01 Research question

The Draft Auckland Plan recognizes that food resilience is likely to be a prized element of city living in the future and that this will place a premium on Auckland and NZ's productive capacity (A. C. Council, 2011). However its overall growth policy is focused toward compact living. Can urban agriculture and suburbia in particular contribute towards food resilience in Auckland?

The specific objectives of this paper are; (a) To estimate potentially cumulative productive land within three suburbs of increasing density in Auckland city. b) Estimate the food energy potential of each site. Based on the results, policy mechanisms, planning and urban design approaches which may be appropriate to integrating UA into urban growth strategies are discussed.

1.02 Why Auckland?

Auckland is New Zealand's largest city with around 401,500 people living within the city boundary and 1.37 million in the greater Auckland area. This represents about one third of the population of the whole country. The city, suburbs and gulf islands cover an area of 637km^2.Auckland is built on a narrow isthmus between two harbours, and is surrounded by extinct volcanoes and picturesque islands. (A. Council, 2000)

Auckland lies in a sub-tropical climate zone, with warm humid summers and mild winters. Typical summer daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C.Winter daytime maximum air temperatures range from 12°C to 17°C. Annual sunshine hours average about 2000. (NIWA, 2008)

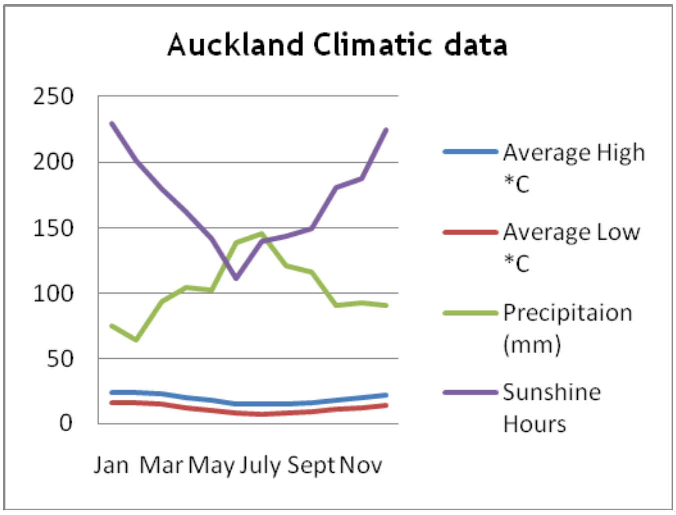


Figure 1

Source: NIWA 2008

1.03 Urban design, transport, food and climate change.

Auckland is a low density city, designed around the car. A typical Auckland suburban home rests on a quarter acre lot. (Longhurst, 2006). New Zealand has one of the highest car ownership rates in the developed world averaging three cars per household. Petroleum and related products form New Zealand's largest imports while vehicles, parts and accessories are the third largest imports. (Statistics, 2011). In 1998, 98 percent of the city's residents lived on the Auckland isthmus with the population density of 22 people per hectare, with the exception of gulf Islands which is below 0.4 percent per hectare. (R. Vale & Pritchard, 2001) quoting (A. Council, 2000) The draft Auckland Plan (A. C. Council, 2011) recognizes the sprawling nature of Auckland and has adopted a compact city growth strategy to mitigate this. However while sprawling cities present a challenge in terms of transport energy consumption, there in, may exist opportunities for innovation in other fields like urban food production.

Urban food production becomes a more attractive option for utilizing suburbia especially for Auckland when looked at in the context of climate change and future competition in energy use between industrial agriculture and hydro-power generation. Half of the energy consumed in New Zealand is from petroleum which is imported. (Ministry of EnergyEnergy, 2011).Oil is a fossil fuel that is peaking in production and there will shortly be not 'enough easy to find oil' to satisfy demand (Hugh 2011).In 2010 the transport sector consumption accounted for almost all the total oil supply in New Zealand which translates to roughly 38.5 percent of the total energy consumption.(Ministry of Economic Development, 2011)

On the surface the agricultural sector accounted for only 5.3 percent of the total national energy consumption (Ministry of Economic Development, 2011) A small percentage without the embodied energy in food. However (Patterson & Earl, 1984) estimated that the New Zealand food system uses around 30% of the nation's primary energy. A similar conclusion was reached by (Barber, 2004) who estimated that renewable energy makes up half of the irrigated arable operations direct energy use at 10,500 MJ/ha or 31% of total energy use.75 per cent of this renewable energy is from hydropower.

Recent figures by (Robert Vale & Vale, 2009) show that embodied energy in food production in New Zealand represent anything between a quarter and a third of the total primary energy consumption. They also add that 10 percent of this energy goes to waste as a result of overeating contributing to obesity, ill health and other environmental ills of overconsumption. A report by the Ministry of Health 2007 points out that over 50 percent of New Zealander's aged 15 years and over are overweight.(Ministry of Health, 2007) In other words, between them, transport and food production account for over 60 percent of the total primary energy consumption in New Zealand.

Another factor is climate change in Auckland. Nationwide the impact of climate change will result in less rainfall in major food producing areas of New Zealand I.e. Canterbury, Northland and Hawkes Bay,(NIWA, 2008). In Auckland temperature are expected to rise up to 2^{o}C for the next 70-100 yrs.(NIWA, 2008). This means long hot summers, loss of soil moisture and nutrients, flooding and droughts which may affect Bombay Hills the traditional food basket for Auckland. Secondly, hydro-power generates 60 percent of New Zealand's electricity supply produced from hydroelectric lakes. (Ministry of Economic Development, 2011)

Hugh (2011) further points out that these lakes have a small capacity and rely on melt water from the snow and glaciers which act as latent water supply. With global warming, the gradual melting of glaciers will result in huge losses of water capacity for hydroelectricity. This all means that a choice will have to make between reserving water for hydro-power generation that supports other sectors like transport and releasing the same water for irrigation to supplement less rainfall resulting from climate change.

All these factors viewed in the context of climate change, possible conflicts between water for hydropower and irrigation suggest future competition for water in industrial agriculture, transport and other sectors

This leaves New Zealand and Auckland vulnerable to food security.

2.00 Relationship between housing patterns and solar availability on the ground

Housing patterns and the resultant density come about as a result of several building developmental regulations. These include, zoning regulations, permitted floor to area ratios and plot coverage. The floor to area ratio refers to the total area of the buildings divided by the total area of the lot on which they are built on. This means that higher floor ratios translate into higher densities while low floor ratios translate into lower densities per lot. Plot coverage refers to the maximum percentage of available land that a building may occupy. This may range between fifty percent to seventy five percent of the total lot area depending on the zoning of the site.

Higher densities in turn may translate to up to three to five story buildings (8m-12m) vertical height of the building. The effect of such heights is the overshadowing effect they may bring about by blocking directing sunlight from reaching the ground level. The overshadowing effect from tall structures reduces the amount of solar reaching the ground and consequently the effective net productive land available for growing crops within a site. If the plot coverage ratio is high, the net available land is further reduced.

The developmental controls and regulations are based on specific urban growth management policies for cities. In order to understand these links an example of the developmental controls for a case study of a residential block within the Mt Eden area is given below.

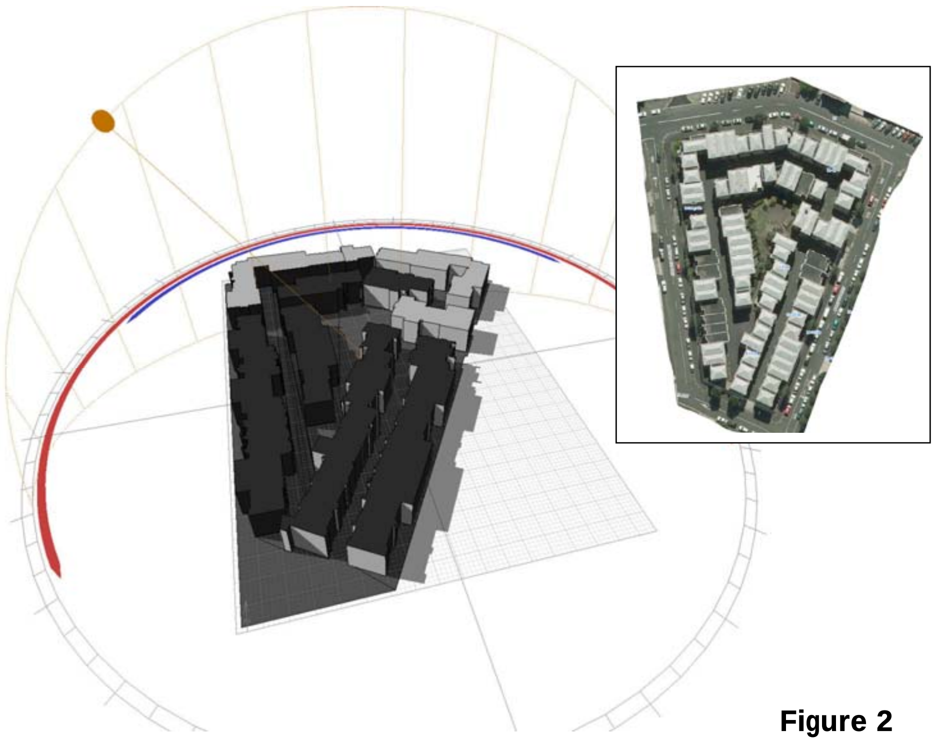


Figure 2

Mt Eden Site Shadow analysis (Source author)

The developmental control rules for this site set the maximum height of structures to 17 metres. 25 square metres of site per person and between 25 and 40 square metres of private open space depending on the sub zone and maximum net plot coverage including buildings and impermeable surfaces of up to 60%.(A. Council, 2000)

The policies and developmental controls give rise to the following densities; population density of 321.5 persons per hectare while household density of 125.3 households per hectare with a population of around 225. The resultant housing pattern is therefore a more compact high density layout of housing units clustered around a courtyard. There are minimum green spaces available with most open spaces being utilized for parking.

The image on the top right hand side represents the site from council GIS viewer. The larger image on the bottom left hand side represents the same block, recreated in archicad and run through Echotech solar analysis software to give an indication of the shadow movement. It is evident that most of the available open spaces within the block fall under shadow generated by the buildings. (Eriksen-Hamel & Danso, 2010) suggest that UA maybe exposed to relatively high shortwave radiation reflected from buildings and paved surfaces which are likely to create heat loads and deplete soil moisture relative to what would be expected when only direct incoming irradiance is measured. This scenario is more likely to happen in high density high rise residential areas with large paved spaces for parking and less green spaces as opposed to suburbia that has green backyards

This contrasts with a suburban block in Sandrigham Figure 3 which has fewer shadows and therefore a large amount of sunshine accessing the ground level

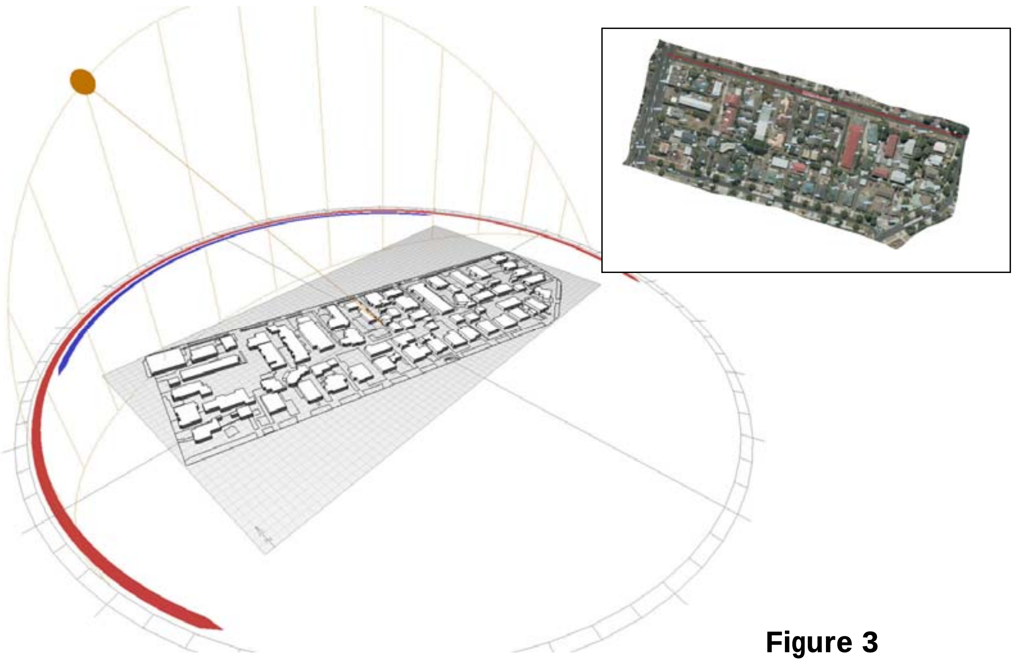


Figure 3

Sandrigham site shadow analysis

Sandrigham Block (fig 2) (meshblock no. 0537700) is zoned as a medium density. It averages a household density of 29.9 per hectare the selected block has a population of 343 and approximately 93 households.

To what extent housing patterns affect solar accessibility to ground level is yet to be empirically determined. However literature review reveals that to some extent urban growth strategies may have an impact on solar access to ground level and ultimately urban agriculture

3.0 Methodology

The selected sites of increasing density were adopted from two previous studies. (Ho & Byrd, 2011) adopted the sites used by (Sumita Ghosh, 2004) for a study on transport energy and city density. These sites have been determined as being representative of Auckland suburbs. The studies also provided detailed density data. The sites were selected on the basis of increasing density from the city center.

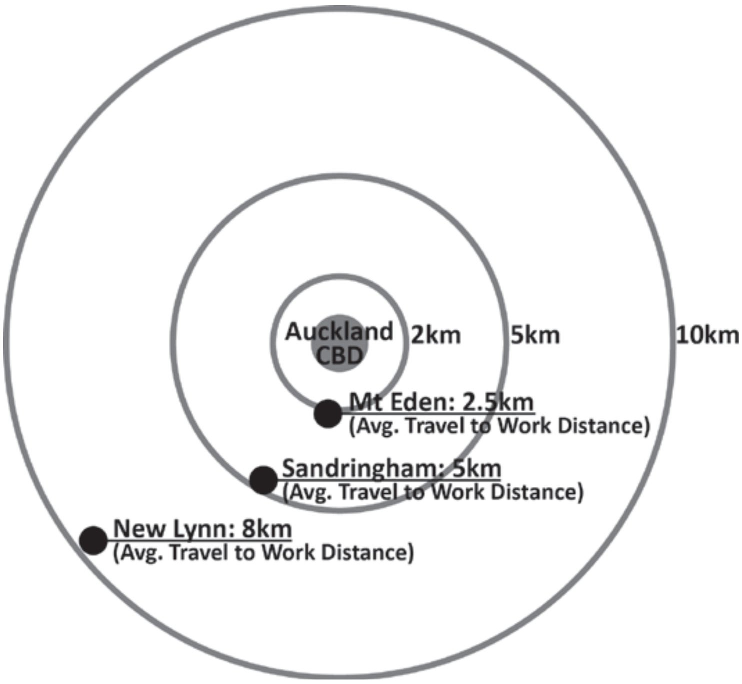


Figure 4.

Three selected suburbs in Auckland showing relative distance from the CBD

Source: (Ho & Byrd, 2011)

Table 1

	Residential block	Density 1 (persons/ hectare)	Density 2 (househd /hectare)	Residents/ household
	Mt Eden	321.5	125.3	2.6
	Sandringham	104.2	29.9	3.5
	New Lynn	47.1	13.5	3.5

Density and occupancy details of selected sites

Source (Ho & Byrd, 2011)

3.01 Steps in estimating available land for urban agriculture from each site

Assumptions made.

Total Land Area would comprise the green lawns under street verges normally maintained by council and fronting the subdivision. The Estimated Potentially Productive Land (PPL) includes domestic garden, shades areas under tree cover and lawn space. This is because it is assumed that if these areas were to be redesigned, most, if not all of this space could be reclaimed for UA.

1. From the Auckland GIS viewer the building foot print and impervious surface maps were extracted. (See New Lynn example below).

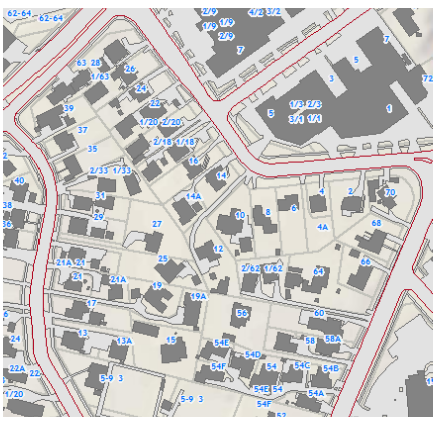


Figure 5

Map of New Lynn from Auckland GIS Viewer

Figure 6

Extract building foot print plan

Figure 7 .Extract impervious surfaces and street verges

2. The plans were extracted as DXF and imported into ArchiCAD software.
3. In ArchiCAD, following the building foot print outline and satellite pictures the sites were recreated.

Figure 8

Combining building foot print and impervious surfaces

4. Using the ‘Fill’ tool set to show area in square meters, in ArchiCAD, the following areas were determined and tabulated: (figure 6.) total site area, street verges, building footprint and impervious surfaces.

5. To obtain potential productive land within each residential block, the subtraction method adopted from transforming Australian cities (Adams, 2009) was used
6. Total land available was taken as total residential block area added to total area comprising street verges. The building footprint and impervious surfaces area were then subtracted from the total land area.
7. The result was an estimate of potentially productive land available in a given suburb. The final figure is gross because it included shaded areas, lawns and recreation space. In some cases mixed UA could occur in such spaces. Such spaces could not be immediately determined as the research focused on potentially available green space. It was also assumed that with proper redesigning some, if not all of the impervious surfaces could be reclaimed for UA
8. The study analysed land available in individual subdivisions and pooled all together to come up with a total figure.

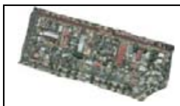
A detailed summary of other sites is given below.

Table 2

	**High density residential**	**M^2 Square Metres**	**(M^2) Square Metres**	**Percentage of total**
Residential Block area	*Add*		6935.29	55%
	Street verges		0	
Total Land Area	*Subtract*		6935.29	
	Building footprint	3,817		
	impervious surfaces shaded areas, lawns etc	2871.69		41%
	Total	6,689		
Potentially Productive Land			246.3	4%

Estimating Potentially Productive Land (PPL) for Mt. Eden (Source Author)

Table 3

	**Medium Density Suburb**	**(M^2)**	**Square Metres (M2)**	**Percentage of total Land**
Residential Block area	*Add*		32928	
	Street verges		2075	
Total land area			**35003(3.5ha)**	
	Subtract			
	Building footprint	13,628(1.36Ha)		39%
	Impervious surfaces, shaded areas, lawns etc	8079		23%
	Total	**21707**		
Potentially Productive Land (PPL)			**13296 (1.329Ha)**	38%

Estimating PPL for Sandrigham (Source Author)

Table 4

	**Low Density Suburb**	**Square Metres (M2)**	**Square Metres (M2)**	**Percentage of total Area**
Residential Block area	*Add*		33,560.80	
	Street verges		503.49	
Total Land Area			**34064.2(3.4Ha)**	
	Subtract			
	Building footprint	13,271		39%
	impervious, surfaces, shaded areas, lawns etc	4841		14%
	Total	18,112		
Potentially Productive Land (PPL)			**15952(1.6ha)**	47%

Estimating PPL for New Lynn (Source Author)

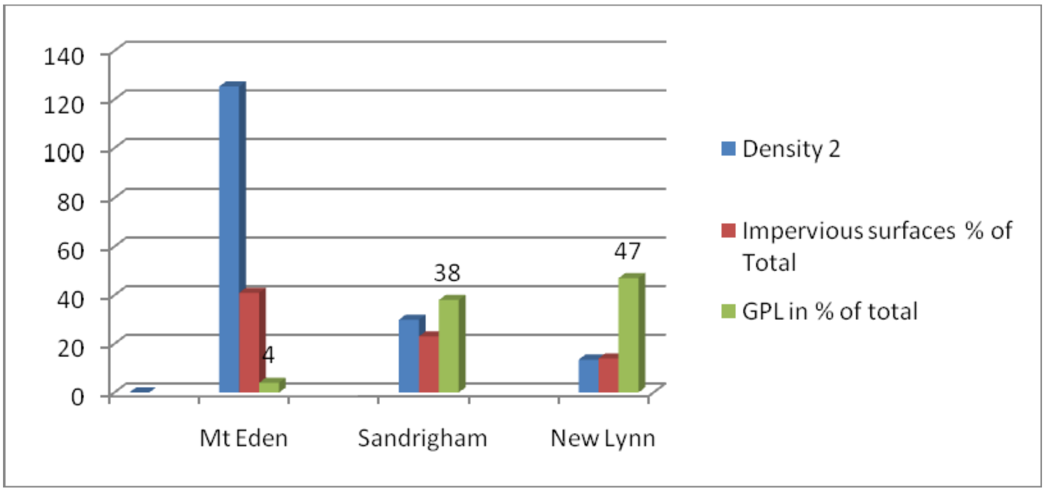
Table 5

Residential block	Density 1 persons /hectare	Density 2 Households/ hectare	Total Land Area (Ha)	Building Foot print (Ha)	Impervious Surfaces, Lawns (Ha)	% of Total	Potential Productive Land (PPL) (Ha)	% of Total
Mt Eden	321.5	125.3	0.7 *(6935M²)*	0.38 *(3817M²)*	0.29 *(2872M²)*	41	0.025 *(246M²)*	4
Sandrigham	104.2	29.9	3.5 *(35003)*	13.6 *(13628M²)*	0.81 *(8079M²)*	23	1.33 *(13296M²)*	38
New Lynn	47.1	13.5	3.4 *(34064M²)*	1.33 *(13271M²)*	0.5 *(4841M²)*	14	1.5 *(15952M²)*	47

A summary of the consolidated densities and areas of the three sites Source: author

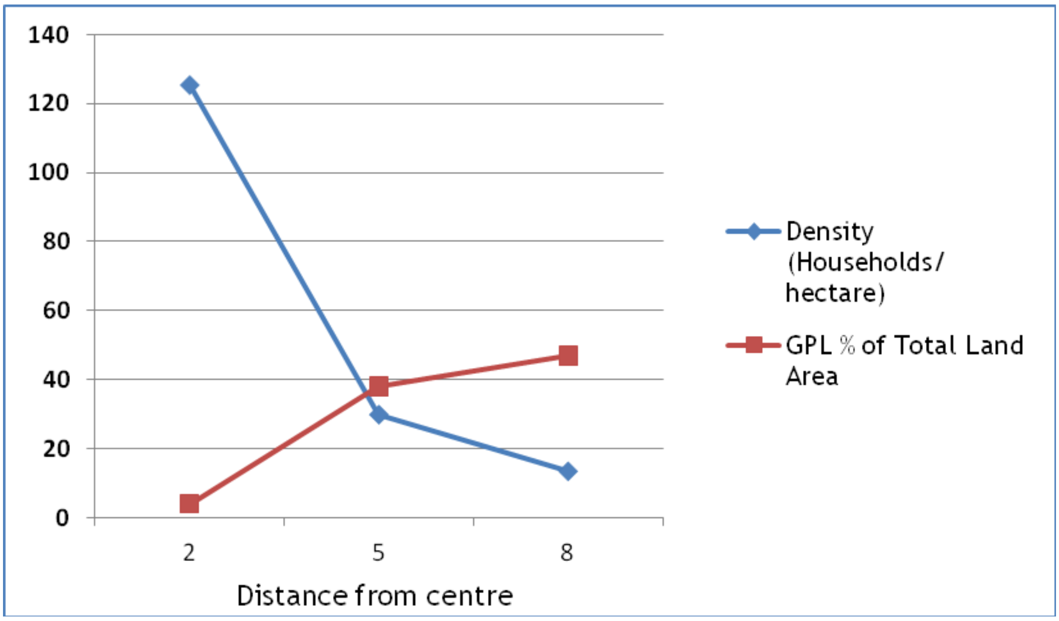
4.01 Results and Discussion.

Figure 9



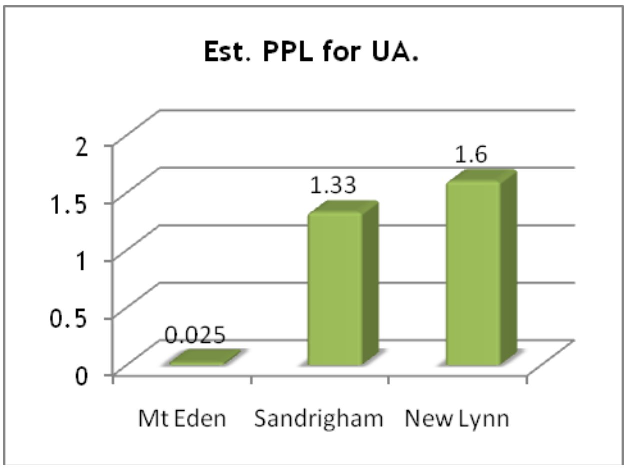
A comparison between HH density/Ha, Impervious Surfaces and PPL as a percentage of the total for the three sites. (Source author)

Figure 10



A linear comparison between HH density/Ha PPL as a percentage of the total for the three sites. (Source author)

As household density reduces from the center, PPL increases.



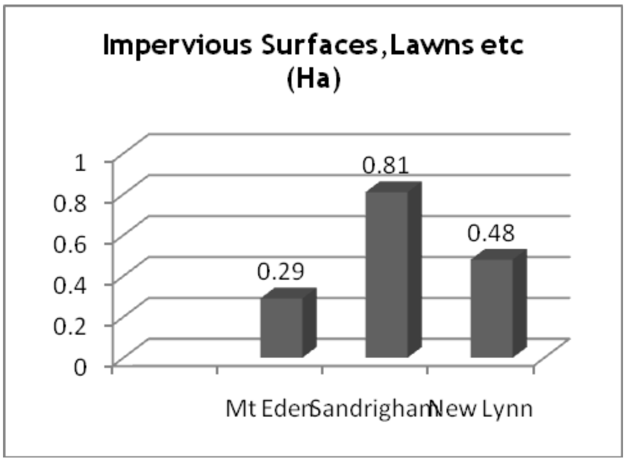


Figure 11 (Source: author) Figure 12 (Source: author)

The results suggest that if all the green spaces, lawns and shaded areas under trees in each subdivision were added together, the Mt Eden Site would produce 246$M^{2,}$ or 0.025Ha, Sandrigham 13,296M^2 (1.33Ha) and New Lynn 15,952M^2 (1.6Ha) of potential land for UA.

4.02 Calculating the food energy potential for the three sites.

Mt Eden had the lowest acreage (0.02ha) or 4% of the total gross area potentially available for farming. Sandrigham had 13.2 Ha (39%) of the total while New Lynn(low density) registered 1.5ha (47%) of the total available land. While the sites had different sizes, the significance issues to note are the ratio of potentially available space for farming to the total site area. The ratio increases with increasing distance from the center and the household density. Also the ratio of impervious surfaces to total site area decreases with increasing distance from the center and household density. However of the three sites Sandrigham had the largest area under impervious surfaces.

The constants used in these calculations and conversion methods of the estimated gross productive land area per site into energy potential for each site has been adapted from methodology devised by (Sumita Ghosh, 2004)

Food expenditure of an average person is 2633 kcal per day or 961,045 kcal per year. This translates to approximately 230 Joules or 2.3 x10^{-7} GJ per year. (1 Kilocalorie (kcal) =4186 Joules, 1GJ=10^9Joules)

a) Total food energy requirement per person per capita per year in New Zealand=5.8GJ per year. Vegetables contribute total 10% of total energy content of the average household diet (MAF 1995 p.78) hence total vegetable energy contributions per household per year is 0.58GJ per year per capita.(excluding embodied energy)

b) Recommend average dietary energy requirements per person per year is 4.2GJ

c) New Zealanders consume 39% in excess of UN FAO recommendations.(Pritchard and Vale 2001)

d) The embodied energy multiplier would be 7.2

e) Food productivity for vegetables per square meter of garden plot per year is 0.007GJ or 1708kcal

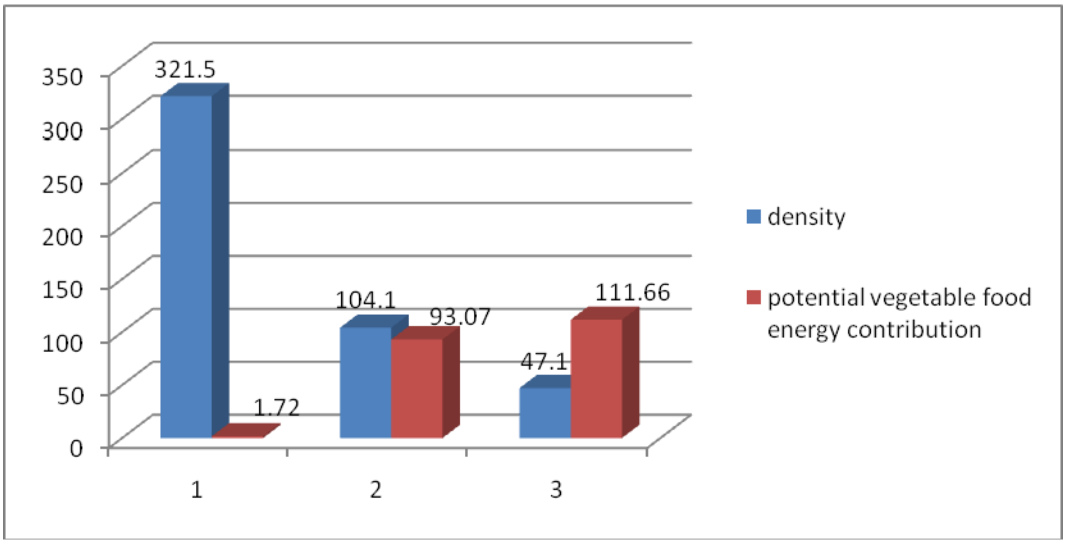
Table 6

Residential block	**Population**	**Density 2 households /ha**	**Est. Gross Productive Land (GPL) (Ha)**	**Conversion Factor in GJ/Year**	**Potential food energy contribution in vegetables in GJ/Year**
Mt Eden	225	125.3	0.025 *(246M²)*	0.007	1.72GJ
Sandrigham	343	29.9	1.33 *(13296M²)*	0.007	93.07GJ
New Lynn	158	13.5	1.6 *(15952M²)*	0.007	111.66GJ

Determining the potential energy in GPL from each site In GJ/Year Excluding Embodied energy (Source: author)

To determine the potential energy in vegetables from Potentially Productive Land (PPL) in each site a conversion factor of 0.007GJ per square metre was used. Thus the Potentially Productive Land in each site was multiplied by 0.007GJ. This resulted in New Lynn with a lower household density having the largest potential energy contribution (111.66GJ/per year).Sandrigham which is zoned medium density had 93.07 GJ/per year while high density Mt Eden had the lowest amount of food energy (1.72GJ/per year).Figure 13 below shows this comparison in a bar chart.

Figure 13



A comparison between HH density/Ha and Potential energy contribution in GJ from each site

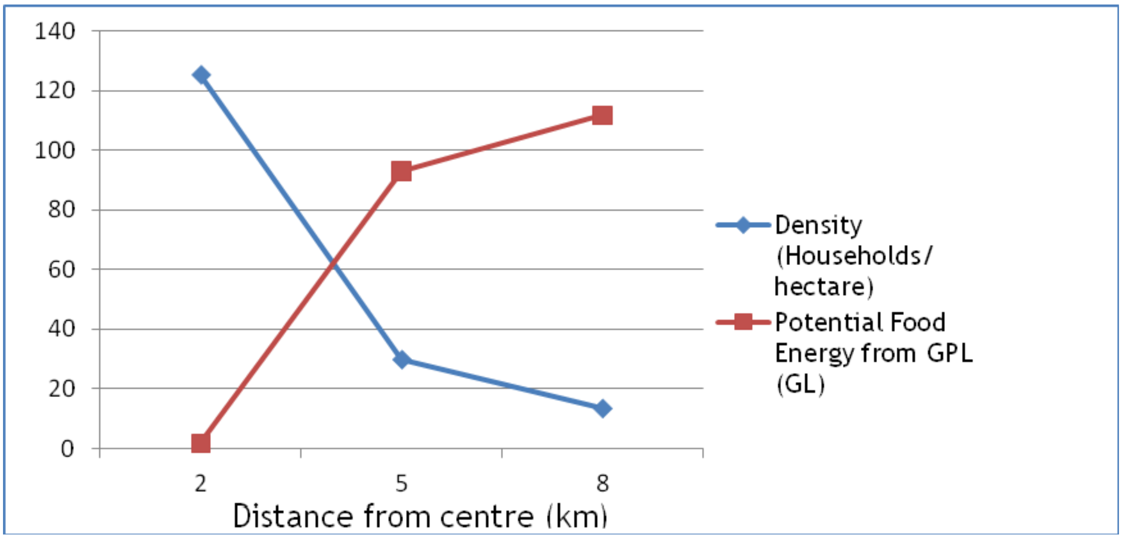
Previous studies (R. Vale & Pritchard, 2001) have determined that New Zealander's consume 39 percent in excess of UN FAO recommended diet. Table Seven has three columns that compare the total energy contribution of vegetables in each of the three sites based on the current consumption rate per person in New Zealand of 0.58GJ/year/capita, the recommended FAO UN dietary requirements and the potential energy available from PPL in each of the three sites. (All these excludes embodied energy)

Table 7

Residential block	Density 2 Households/ha	Est. Gross Productive Land (GPL) (Ha)	Current Energy in NZ in vegetables consumption 10% of total diet (Conversion factor 0.58GJ	Energy Contribution for Vegetables (recommended Conversion factor (0.42GJ)	Potential food energy contribution From PPL in vegetables
Mt Eden	125.3	0.025 *(246M^2)*	130.5	94.5GJ	1.72GJ
Sandrigham	29.9	1.33 *(13296M^2)*	198.9	144.06GJ	93.07GJ
New Lynn	13.5	1.6 *(15952M^2)*	91.64	66.36	111.66GJ

A comparison between current energy in New Zealand Vegetable requirement, Energy in recommended UN FAO diet, and Energy in Vegetables produced from PPL in each of the three sites. (Source Author)

Figure 14



HH density per hectare vs. Potential Energy from GPL for the three sites. (Source author)

At the current consumption rate, only the low density New Lynn block can successfully provide the recommended FAO UN equivalent of vegetable dietary requirement and still have a surplus of 45.3GJ per/year. However even if this surplus were to be added to the deficit in the Sandrigham or Mt Eden block, the overall figure would still not be enough to satisfy the UN FAO recommended dietary requirements. It falls short by 5.0GJ for Sandrigham and almost 50GJ for the Mt Eden deficit. Additionally to meet the current NZ consumption rates the Mt Eden site has to completely rely on food produced off site while Sandrigham site would need Potentially Productive Land that is twice as much as what is currently available. i.e atleast 2.6ha. Again only the low density New Lynn block can successfully sustain itself both under the current NZ consumption rates and the UN FAO recommended minimum energy diet requirements. However for medium density Sandrigham, converting some of the impervious surfaces into productive land, could significantly contribute to increasing productive land.

4.03 Can urban growth strategies integrate urban agriculture? Urban planning and design policy implications.

Analysis of the three sites shows that a higher potential for UA exits in low density-New Lynn and medium density-Sandrigham suburbs. Of the total available land on site in New Lynn, 47 per cent of the total was potentially available land for UA while Sandrigham had up to 38 per cent. Only four per cent of high density Mt. Eden could be available for UA although the potential for roof gardening was not considered. This may fundamentally increase the potential for Mt Eden if all of the roofs were flat. In terms of potential food energy contribution to the overall diet only low density New Lynn was self-sufficient. Sandrigham could meet over 75 per cent of its vegetable requirements while Mt Eden had to completely rely on food produced off site to meet its dietary requirements.

Results suggest the need for urban growth management strategies to integrate UA within their framework. Lee Smith, a widely acknowledged authority in UA points out in an interview with Zuckerman 2011 that the idea of a sterile, futuristic city with no farmers should be replaced with the idea of a city that integrates farming into all aspects of planning. (C.Zuckerman, 2011). Currently the Draft Auckland Plan, while recognizing the importance of food resilience in New Zealand and Auckland in particular, does not set out strategies of how to achieve this.

Studies by (S. Ghosh, Vale, & Vale, 2006) recommend that to achieve the 'most efficient urban form' behaviour change and appropriate policy measures are critical for the uptake of local food production in home gardens. Following up on such recommendations, one way could be to remind New Zealanders of their long standing tradition with home gardening and the place 'garden space' holds in Kiwi culture. (Longhurst, 2006) describes the huge social, cultural and political significance 'plots and plants' hold in New Zealand.

She points out that the New Zealand domestic garden is referred to as a 'Kiwi Icon' and that New Zealanders love gardening to the extent that it sometimes takes on a religious fervor. Perhaps replacing and/or mixing aesthetic gardening with food production could go a long way in stimulating behavior change towards embracing home gardening in terms of food production.

Aligning UA policy with New Zealand's history on home gardening would ensure public support and commitment in implementing such policy. Indeed support for the local farmer has been internationally acknowledged in a report by the **International Assessment of Agricultural Knowledge, Science and Technology for Development,(**IAASTD., 2009**)** which calls for a shift away from industrial agriculture and toward the small-scale farmer, 'wherever she might sow' (C.Zuckerman, 2011)

Another strategy lies in identifying suburban spaces for UA as 'green lungs' of the city. These study has shown that medium to low density suburbs have potentially productive land for UA. These would complement the compact city strategy of concentrating development around town centers and transport corridors while leaving suburbia for UA. It also answers the question of what role suburbia can play within the realm of the smart growth machine as pointed out by (Haarhof & Beattie, 2011) quoting (Hayden, 2002)

However one question remains as to how to incentivize suburban owners to consider private backyards for UA especially for commercial purposes. One way to achieve this would be for local governments to adapt the solar energy strategy like that of New York City. The City of New York working with the City University of New York recently devised The NYC Solar Map 2011. The Map is an interactive online tool that allows users to estimate the solar energy potential for every building in New York City's five boroughs by inputting an address. (Center for Applied Research for Spatial Information, 2011)

These data is also available to possible investors who may want to rent out certain roofs for solar energy generation. The city has also established solar empowerment zones. These are areas where installing solar systems will provide the greatest energy benefits for New Yorkers.

A similar approach could be structured for UA in the suburbs. A data base of potentially fertile backyards receiving adequate solar energy for UA in medium to low density suburbs within Auckland and associated crops yields and energy savings could be maintained by council. Council could designate such areas as UA empowerment zones where opportunities and incentives for investing in UA are available. Interested UA farmers and groups could then enter into contract with home owners to rent out one or more backyards for UA. This arrangement presents a win-win situation for both parties as both get income in form of rent and sales from the UA products while council provides oversight. The council benefits for having more 'green spaces' complimenting the monotony of impervious surfaces that characterize compact city.

Perhaps an overall strategy would be for local authorities to recognize UA as a legitimate land use and establish zoning ordinances aimed at promoting and protecting it. Such laws would include but not limited to;

a)Identifying and eliminating any zoning, design or other restrictions on home gardens and edible landscaping on residential properties, including single family, multifamily and residential mixed use. (Wooten & Ackerman, 2011)

b) A law requiring district plans, comprehensive plans and other developmental plans to include an 'urban agriculture plan' as one of the key elements.

c)A law requiring new developments to set aside within the scheme an appropriate amount of land for a community garden among others.

Site layout and ultimately building orientation and height influences the amount of sunlight that reaches the ground by casting shadows. This affects the rate of photosynthesis that takes place in plants especially vegetables and most C3 plants that are mostly grown in backyard gardens. At the initial design stage architects, landscape architects and urban designers should take into account sun studies to determine the perfect sighting for garden orientation. Just like solar analysis is done during passive design for buildings, so should an analysis be done to determine the amount of solar reaching the ground as an indicator of productivity.

5.0 Conclusion

There exists high potential for UA in medium to low density suburbs with high density suburbs showing little or no potential unless roof gardening is considered. If food energy potential is considered,excluding embodied energy, the low density suburbs are self-sustaining while the medium to high density residential blocks would need a supplement of food grown offsite to meet half of their annual vegetable dietary requirements. Within the realm of the compact city strategy, medium to low density suburbia could play the role of 'green lungs' for the city supplementing the food deficit in high density residential blocks while acting as the green spaces that relieve the monotony of continuous 'hard' surfaces associated with compact living.

Ultimately UA may not replace industrial agriculture as a major source of food supply to cities. Pressures on agricultural lands brought about by climate change and fluctuating energy prices all contribute to future unsustainability of industrial agriculture. Moreover growth strategies that promote compact city concept will fundamentally exacerbate the scarcity of land in urban areas for UA. However the potential of available land in suburbia and its access to solar energy provides one way to relieve such pressures while providing local and fresh produce to city dwellers.

Bibliography

Adams, R. (2009). Transforming Australian Cities for a More Financially Viable and Sustainable Future: Transportation and Urban Design. *Australian Economic Review, 42*(2), 209-216. doi: 10.1111/j.1467-8462.2009.00550.x

Barber, A. (2004). Seven Case Study Farms:Total Energy & Carbon Indicators for New Zealand Arable & Outdoor Vegetable Production

Retrieved from agrilink.co.nz website: http://www.agrilink.co.nz/Portals/Agrilink/Files/Arable_Vegetable_Energy_Use_Main_Report.pdf

C.Zuckerman, J. (2011). The Constant Gardeners. *OnEarth*. Retrieved from A Survival Guide for the Planet OnEarth website: http://www.onearth.org/article/the-constant-gardeners

Council, A. (2000). http://www.aucklandcity.govt.nz/ Retrieved 02/02, 2012

Council, A. C. (2011). The Draft Auckland Plan, 2011, from http://www.acklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/theaucklandplan/draftaucklandplan.pdf

Development, M. o. E. (2011). *The New Zealand Energy Data File*. (ISSN 1177-6684). Wellington: Ministry of Economic Development Retrieved from www.med.govt.nz/energy/edf/.

Energy, M. o. (2011). *New Zealand Energy Strategy 2011-2021*. Wellington: Ministry of Energy Retrieved from http://www.med.govt.nz/sectors-industries/energy/pdf-docs-library/nz-energy-strategy-lr.pdf.

Eriksen-Hamel, N., & Danso, G. (2010). Agronomic considerations for urban agriculture in southern cities. *International Journal of Agricultural Sustainability, 8*(1-2), 86-93. doi: 10.3763/ijas.2009.0452

Ghosh, S. (2004). *Simple Sustainability Indicators for Residential Areas of New Zealand.* Doctorate PHD, Auckland, Auckland. Voyager: BID2078332 database. (G427 2004)

Ghosh, S., Vale, R., & Vale, B. (2006). Domestic energy sustainability of different urban residential patterns: a New Zealand approach. *International journal of sustainable development, 9*(1), 16-37.

Haarhof, E., & Beattie, L. (2011). *Questions about smart growth: a critical appraisal of urban growth strategies in three North American Cities*

Hayden, D. (2002). What is suburbia? Naming the layers in the landscape, 1820-2000. In I. T. S. S. A.Carbonell (Ed.), *Smart growth: Form and Consequences*. Toronto: Lincoln Institute of Land Policy

Health, M. o. (2007). *An Indication of New Zealanders' Health 2007*. (4488

). Wellington: Ministry of Health Retrieved from https://www.health.govt.nz/publication/indication-new-zealanders-health-2007.

Ho, A., & Byrd, H. (2011). *Transport energy and city density: a case study of how renewable energy can reverse the curve.* Paper presented at the 45th ANZASCA, Sydney.

IAASTD. (2009). Agriculture at Crossroads-Global report. In H. R. H. Beverly D. McIntyre, Judi Wakhungu,Robert T. Watson (Ed.), *Global Report*. Johannesburg: International Assessment of Agricultural Knowledge,Science and Technology for Development.

Information, C. f. A. R. o. S. (2011). NYC Solar Map Retrieved 01/03/2012, 2011, from http://www.cuny.edu/about/resources/sustainability/solar-america/map.html

Longhurst, R. (2006). Plots, plants and paradoxes: contemporary domestic gardens in Aotearoa/New Zealand. *Social & Cultural Geography, 7*(4), 581-593. doi: 10.1080/14649360600825729

NIWA. (2008). Climate Change-Projections for New Zealand. Retrieved from Climate Change Scenarios For New Zealand website: http://www.niwa.co.nz/sites/default/files/import/attachments/IPCC_08_report_02s.pdf

Patterson, M. G., & Earl, M. D. (1984). Energy use in the New Zealand food system. *Energy in Agriculture, 3*(0), 289-304. doi: 10.1016/0167-5826(84)90037-8

Statistics, N. Z. (2011). New Zealand in profile 2011-Imports and Exports Retrieved 02/02, 2012, from http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-in-profile-2011/imports-exports.aspx

Vale, R., & Pritchard, M. (2001). The Real Cost of Food: A White Paper. An analysis of the environmental impact of food production.

Vale, R., & Vale, B. (2009). *TIME TO EAT THE DOG? The real guide to sustainable living* (First ed.). London: Thames and Hudson Limited.

Wooten, H., & Ackerman, A. (2011). Seeding the City: Land Use Policies to Promote Urban Agriculture. *The National Policy and Legal Analysis Network to Prevent Childhood Obesity (NPLAN)*. Retrieved from nplan.org website: http://www.nplanonline.org/