INSTITUTO TECNONÓLOGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

FINAL PROJECT REPORT

The Impact of Urban Agriculture in Sustainable Cities.

Author(s):
A01169284 - Bruno González Soria
A01212611 - Antonio Osamu Katagiri Tanaka
A01750267 - Carlos Cardoso Isidoro

Instructor(s):
Diego Fabián LOZANO García
Rosa María LÓPEZ Franco

A project report submitted in fulfillment of the requirements for the course of Leadership for Sustainable Development

in

ITESM Campus Estado de México
School of Engineering and Sciences

Estado de México, Atizapan de Zaragoza, May 12, 2019

INSTITUTO TECNONÓLOGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

Abstract

Faculty: Nanotechnology

School of Engineering and Sciences

Leadership for Sustainable Development

The Impact of Urban Agriculture in Sustainable Cities.

by **A01169284** - Bruno González Soria
A01212611 - Antonio Osamu Katagiri Tanaka
A01750267 - Carlos Cardoso Isidoro

The implications of urban agriculture in a sustainable city is unresolved in the conventional literature. The purpose of this report is to: 1) review relevant literature to address the impact of urban agriculture in sustainable cities; and 2) develop a software tool for educational purposes in order to ease the starting urban agricultural process for the average citizen. The results from this report comprises: 1) a synthesis of the literature that indicates that urban agriculture supports the economic, social and environmental sustainability of cities; and 2) an Android application (Garden Gem). Nevertheless, if the economic dimension of sustainability is only considered, then urban agriculture is not feasible, as the economic benefits non-agricultural activities (such as commercial or industrial) are significantly greater. However, the social and environmental impacts of urban agriculture are be difficult to quantify. The social and environmental impacts are underestimated in the city landscape.

keywords: android, technology, mobile application, Garden Gem, sustainable cities, compact cities, urban agriculture, urban land planning

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1 Introduction

The rapid urbanisation ease accessibility to urban agriculture as it becomes more profitable [90]. Consequently, farmers who are unable to compete rural areas due to their low bid rents, have been languished by the urban market [6, 7, 49, 75]. The William Alonso's bid-rent theory explains how land users are willing to pay high rents for an area of land in an open and competitive land market [84, 15, 36]. William Alonso's theory explains the need to allocate city land to uses that produce the most net income within a given time [36]. Accordingly, governmental authorities give advantages to non-agricultural activities in the city land allocation. Therefore, agriculture has been limited to the urban periphery and rural areas.

Moreover, the rapid urbanisation in the south of the planet, are threatening the sustainability of agriculture in both the urban periphery, and the rural areas [6, 59]. United Nations estimates that by 2020, the developing countries of Africa, Asia and Latin America will house approximately four main urban areas, and nine mega-cities in the globe. Furthermore, by 2030, approximately 66% of the world's population will be located within the cities' boundaries. High demand for urban lands leading to their allocation to the highest and best use will be caused by the increase in the city's population. On the other hand, agricultural land in the urban periphery will continue to be invaded by other land uses, which could negatively impact the food security and poverty levels [44].

Urban agriculture can only be sustained if governments consciously integrate agriculture into the city land use planning and zoning. However, the city authorities, particularly in the global south, have given little to no intention to attend agriculture matters to make cities sustainable (as stated in the 11th Sustainable Development Goal). The authorities apparent belief that the highest and best use of city land is not to allocate it to agricultural uses. This belief may have been fuelled by the lack of clarity in the narrative in the conventional literature about the role of urban agriculture in building sustainable cities. The erroneous belief can be clarified with current literature. Agriculture in cities performs economic, social and environmental functions, which contribute to the sustainability of cities. For instance, agriculture in cities in Sub-Saharan Africa complements the nutritional needs and food costs [17]. In Yaounde, Cameroon, urban farmers consume around a quarter of the crops they produce [80], in Ghanaian cities, urban farmers supply almost all vegetables (lettuce and onion) that are consumed in cities [50, 32]. The works of Ackerman et al. [2], Opitz et al. [74], Specht et al. [85] and Ayambire et al. [12] stress out the role of urban agriculture in food security.

Along with the economic roles, urban agriculture performs social and environmental functions. The environmental functions are in the forms of air and water quality improvements [57], and pollination and bio-control activities [57, 24]. The social functions are evident in its support for political activism and voluntarism in cities. For instance, Obach and Pole showed that farmers in New York City are more likely to engage in voluntary works for community development than the general population [72, 79]. On the other hand, farms in Dar-es-Salaam, Tanzania, are used as "rallying grounds" for political parties during the election processes [65]. Dimitri et al. [31]. Urban farms also provide educational and community building functions.

The discussion points to the intimate role of urban agriculture in the sustenance of cities. Veenhuizen [92] suggests that urban agriculture is prone increase the workload on women as they are usually responsible of the household duties and the agricultural activities. Moreover, urban agriculture in the Earth's south countries, has been known to stimulate child labour and school deviation [33, 46]. On the other hand, the use of agro-chemicals [5, 3] with the use of untreated waste-water for irrigation [6, 7, 16, 61, 69] have unfavourable consequences in health and environmental matters.

It is known that city authorities are not willing to make significant attempts to integrate urban agriculture into the city land use planning and zoning. Amponsah et al. [6, 7] state that city authorities in Kumasi and Accra in Ghana exclude agriculture land use in the cities plans. The difficulty in measuring the social values and environmental services may lead to a misunderstanding of the need of urban agriculture. The aim of Garden-Gem is to support the relation between urban agriculture and sustainable cities by providing general knowledge about agriculture to the general public.

2 Theoretical Framework

This section of the report provides with an overview of urban agriculture and its objectives with a theoretical framework of a sustainable city.

2.1 Overview of urban agriculture

The Food and Agricultural Organization defines urban agriculture as any production in the home or within urban area [35]. In relation to the FAO definition of urban agriculture is the understanding that urban agriculture also implements the practices of farming and gardening in rural areas [74]. Some organisations limit their description of urban agriculture to gardens and farms within the inner city [27], others include agricultural activities in the urban periphery area [68]. Thebo, Drechsel, and Lambin [89] state a distinction between urban agriculture and urban periphery agriculture based on geographical location. Thebo et al. indicate that urban periphery agricultural activities take places within a distance of 10 to 20 Km of the urban boundary. Based on Thebo's et al. distinction, the present paper addresses only agricultural activities that take place within an urban boundary. The work of Ayambire et al. [12] gives a detailed distinction between urban and urban periphery agriculture.

The purpose of urban agriculture varies between cities. In the northern globe, people farm typically for recreational reasons although farming for household food supply [64]. In the southern globe, farming is mainly to satisfy household food needs and other commercial reasons [7, 64]. Normally, households in the cities in the global south farm mainly for household consumption. On the other hand, rooftops, balconies and parks are used for agricultural purposes within the cities in the global north [64]. In this context, urban agriculture is implemented in this paper to study crop farming done through community gardens, backyard gardens and rooftops.

2.2 Conceptualising a sustainable city

The concept of sustainable cities originated in the United Nations World Commission on Environment and Development's (UNWCED) idea of sustainable development. The UNWCED summarised sustainable development as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. The concept has been a standard to address many areas of human activity. Sustainable cities determines the way humans shall interact with nature, as well as the way human shall take responsibility towards one another and future generations [97]. Lew, Ng, and Ni [56] suggest that numerous definitions of sustainability and sustainable development are vague due to the varied understanding of sustainable development and the numerous definitions of sustainability [66]. "Environmental economists believe in economic reductionism by undervaluing ecological goods while social ecologist is reductionist-holistic by focusing on the domination of people and nature." [66] These lead to the separation of nature, economy and society, which is problematic for sustainability purposes. This report focus on sustainable development considers its tripartite dimension (economic, social and environmental).

The 11th SDG (Sustainable Development Goal) amplifies the sustainable city definition, which is "to make cities and human settlements inclusive, safe, resilient and sustainable. The concept is influenced by the rapid urbanisation of the world and the effects on the environment. The implication is that sustainability should be an imperative objective in every development plan. In this regard, the main goal of urban development shall be to make cities and ecosystems sustainable [43].

The compact city concept describes a city that is energy-efficient and less polluting due to the proximity of houses to the commercial areas and work places. The focus is on high density cities, which will result in less commute, efficient transportation and decreased emissions [1]. Typically, compact cities have less space for green-infrastructure due to the space limitations that have a negative effect on the quantity and quality of vegetation. Liu et al. have shown that compactness can have negative effects on domestic spaces, affordable shelter, and increased crime levels [59]. These effects contradict the principles of a sustainable city, which target a balance among economic development, environmental protection, and equity in income, employment, shelter, services, infrastructure and transportation [**Hiremath**]. For this reason, Garden Gem is not intended (but not limited) to be used within a compact city environment.

Models and indices are also based on conceptual terms. For that reason, the following lists the strengths and weaknesses of three indicators to measure a sustainable city. The use of indicators allow a detailed and quantitative way to measure sustainability within a city. This report reviews the existing models (the Green City Index, Global City Indicators Facility and the Global Compact Cities Circles of Sustainability) to develop a framework for a sustainable city. The framework intention id to serve as the basis for the role of urban agriculture in sustainable cities.

2.2.1 The Green City Index

The Green City Index is known as one of the robust models for the identification of a sustainable city [45]. It comprises thirty indicators, grouped in eight categories. The categories comprise

- Environmental governance
- Carbon dioxide (CO2)
- Buildings
- Transport
- Water
- Waste and land use
- Energy
- Air quality (refer to Appendix A).

The benefits of this model is the ability to be applied in several geographical contexts. The index has been the implemented in the following reports: African Green City Index, Asian Green City Index, European Green City Index, German Green City Index, Latin American Green City Index, and U.S. and Canada Green City Index [45]. The wide application of the model, its comprehensiveness and attribute as a "strong sustainability indicator" Huang et al. [45].

The indicators on carbon dioxide (CO2), which aims to reduce emissions, are directly linked to the indicators on transportation and air quality. The use of non-car transportation and increased use of green transport will most likely lead in the improvement of air quality. The indicators on energy are directly linked to the indicators on buildings. The management of energy consumption and the increase in the use of renewable energy are most likely to result in energy-efficient buildings.

2.2.2 Global City Indicators Facility

The Global City Indicators Facility attempts to include most aspects of urban cities, with a focus on economic and social matters (refer Appendix B). The model defines a sustainable city based on its economic and social structures. The Global City Indicators Facility was created by the World Bank, working with the Japanese Trust Fund. Its weakness is the lack of focus on pollution, air quality, CO2 emissions, and renewable energy. Moreover, indicators on waste-water, water and particulate matter emissions are considered in the Global City Indicators Facility. The Global City Indicators Facility is designed to focus on cities with a population of over 100 thousand [63].

In another vein, the Green City Index and the Global City Indicators Facility agree on the use of specific indicators such as solid waste, transportation, waste-water, water consumption and energy. However, they do not cover aspects of food, flora and fauna. These are essential requirements for sustainable cities [2, 74, 85].

2.2.3 Global Compact Cities Circles of Sustainability

The Global Compact Cities Circles of Sustainability is used to assess the sustainability in a city. It has been used by various cities such as Johannesburg, Melbourne, New Delhi, São Paulo and Tehran and by various organisations such as the UN Global Compact Cities Programme, World Vision and Save the Children to address sustainability efforts. The Global Compact Cities Circles of Sustainability is based on 28 indicators (refer to Appendix C), which are categorized in four sub-categories.

The weaknesses of the Green City Index and the Global City Indicator Facility in not providing food flora and fauna measurements are covered by the Global Compact Cities Circles of Sustainability. An analysis of the Global Compact Cities Circles of Sustainability shows some similarities with the Green City Index and Global City Indicators Facility in regards to health, education, gender, technology, infrastructure, waste, water and air indicators. The indicators in the Global Compact Cities Circles of Sustainability are supportive. For example, reducing emissions and waste are prone to improve the habitat, settlements, recreation, identity of an area. Nevertheless, the Global Compact Cities Circles of Sustainability, unlike the Green City Index and the Global City Indicators Facility, does not address the environment, energy management and social engagement.

The report addresses a framework that merges the three indicators to measure sustainability in the three dimensions: economic, social and environmental. Figure 3.1 illustrates the combined framework presents the indicators that were used to assess the relation between urban agricultural and sustainable cities.

3 Methods

The evidence on indicators for sustainable cities is reviewed and analysed to build a sustainable city framework, which was used to analyse the relation between urban agriculture and sustainable cities, and the effect that Garden Gem may have in those indicators. The conceptual framework was developed from the following models: a) the Green City Index (Appendix A), b) the Global City Indicators Facility (Appendix B) and c) Global Compact Cities Circles of Sustainability (Appendix C). The framework includes the advantages of each model and addresses the weaknesses of a single model. The indicators were then categorised in three denominations: economic, social and environmental. See Figure 3.1.

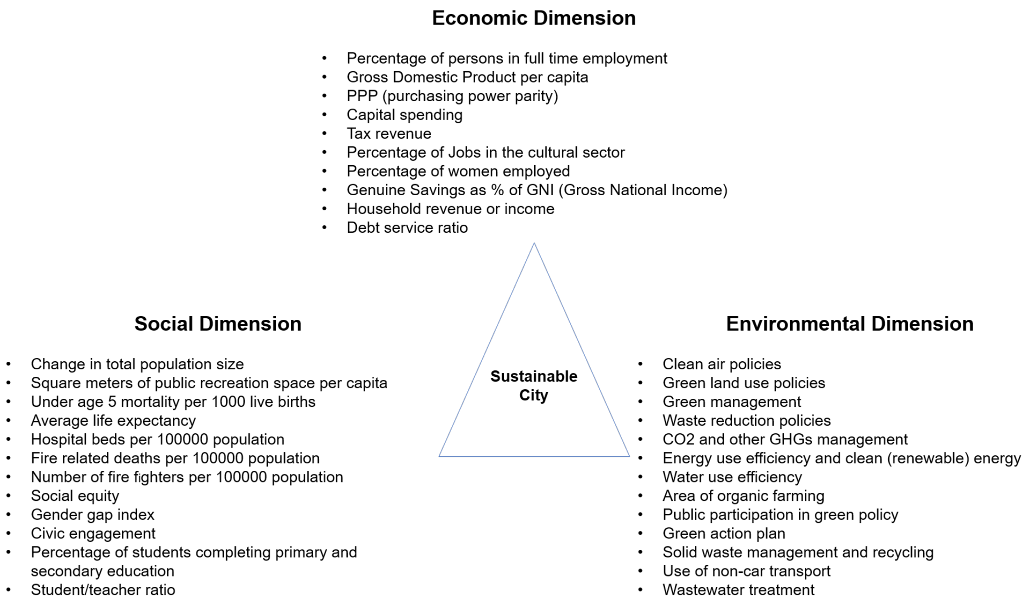

FIGURE 3.1: Sustainable City Framework.

The report is addressed from several geographical locations with different climatic, economic, social and environmental features. The report intents to state the importance of urban agriculture in the sustainable city. For instance, in the global north, the importance of urban agriculture is more environmental in nature than socio-economic. However, the social and economic functions of urban agriculture are in need within the cities in the global south. Despite the differences, the sustainable city framework in the present report ties together economic, social and ecological indicators and can be applied in every city. The selection of the crops to cultivate to achieve the sustainability goals would be based on the local climatic conditions. On the other hand, the indicators listed in the the sustainable city framework, will be used to identify the impact of Garden Gem in the sustainable city.

3.1 Garden Gem Development

The methodology to follow in order to get the best contribution to urban agriculture is first to develop some surveys that can help having a better and more realistic view of the current situation of the way agriculture is done in cities.

Once the data has been gathered, the next step is the development of a mobile application that considers all the issues and situations regarding growing plants. The application must be provided by this information so it can give more accurate information related with growing plants.

The next step is for the user to enter the information about the plants that wants to grow. The application must be able to provide the user with a detailed description of the necessary growing conditions in order to make plants grow better despite all conditions that may affect their growing, depending on the issues found for the given plant.

Finally, the application must be tested by real users in order to get the necessary feedback to verify the correct operation of the application. Thus, the development of the application could be validated and considered for furthermore applications.

4 Analyses

As presented in Figure 3.1, the indicators for measuring a sustainable city are categorised into economic, social and environmental. This section of the report links the relation between urban agriculture and sustainable cities with reference to the indicators under each of the dimensions.

4.1 Urban agriculture and economic sustainability of cities

4.1.1 Full-time employment

Urban agriculture provides employment, and has become a means of a style-of-life, for people in cities particularly in the global south [50, 99]. An estimated two thousand one hundred farm labourers in Morogoro and six thousand four hundred in Mbeya, Tanzania are involved in urban agriculture [46]. In the same way, approximately a hundred twenty thousand low-income households in Manila, Philippines depend on the local/urban jasmine production for their livelihoods [47]. Urban agriculture's role in employment creation abound in literature [7]. See Table 4.1.

TABLE 4.1: Number of people engaged in urban agriculture in the global south. [35].

Region	Number (million)	Principal live-hood
Sub-Saharan Africa	11	Commercial vegetable growing or dairy farming
Northern Africa and the Middle East region	6	Horticultural and livestock products (fruit, vegetables and poultry)
South Asia	11	Perishable high-value commodities such as milk and fresh vegetables
East and South-East Asia	7	Perishable high-value commodities such as milk and fresh vegetables

Urban agriculture is a source of employment to farmers but it is also to stakeholders in the supply chain, see Figure 4.1. The community of farmers and delivers in Argentina, Brazil and Uruguay are examples of jobs created in the commercial sector by urban agriculture [46]. In the same way, most vegetable farmers in urban Ghana deliver their produce to wholesalers, who are predominately women [8, 5]. These wholesalers in turn sell the produce to retailers, food vendors and households as depicted in Figure 4.1.

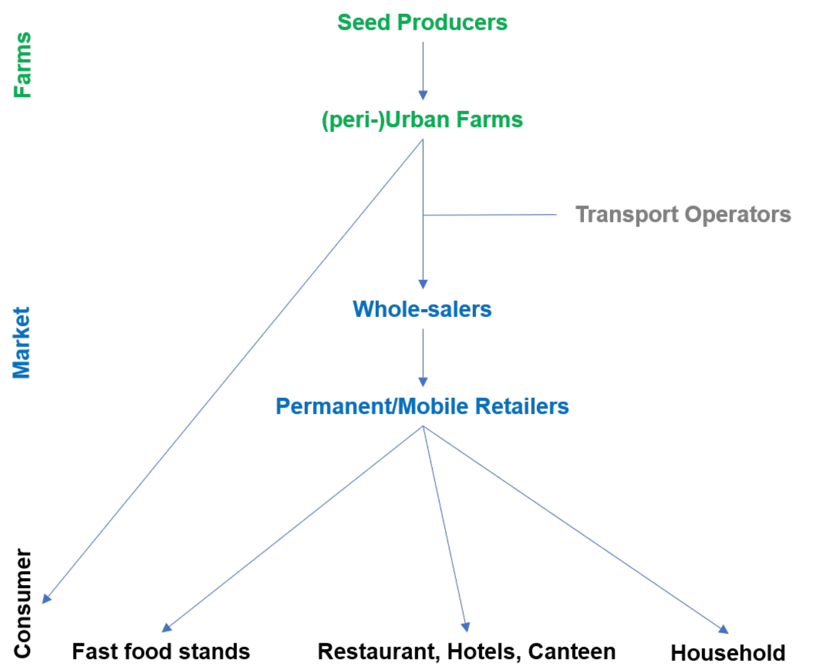

FIGURE 4.1: Flow chart of vegetable supply chain. [32]

Urban agriculture has a significant contribution to the employment of the members of a city in the southern globe. In the cities in the global north, the motivation for authorities to stimulate agriculture in these cities is due to the ecological functions as well as the support for recreation areas [78]. Urban agriculture in the northern globe is not economically-centred but in its environmental functions. Nonetheless, recent studies state that urban agriculture in the global north is gradually shifting from leisure to urban sustainability [64].

4.1.2 Employment for women

Prain and Lee-Smith [80] state that two of three urban farmers in Yaounde, Nakuri, Maputo, Nairobi and Kampala are women. Typically, these women farmers engage in farming with the goal of providing their family needs of nutritious, chemical-free and fresh food [37]. Urban women farmers also sell the excess produce for income. Nevertheless, agriculture could be a bad thing to these women as they perform many tasks at the household. [92]. Therefore, a conscious effort by policy makers and social advocates is required to minimise the workload on women from the combination of household errands and economic activities in urban agriculture.

Generally, commercial urban agriculture is dominated by men as described in Table 4.2. However, women are more present in the food market [32]. It can therefore be deduced that commercial agriculture in the cities in the global south is gendered and thus makes a significant contribution to employment for both genders.

TABLE 4.2: Gender in urban agriculture in selected cities. [5]

Country	City	Female (%)	Male (%)
Benin	Cotonou	25	75
Burkina Faso	Ouagadougou	38	62
Cameroun	Yaoundé	16	84
Cote d'Ivoire	Abidjan/Bouake	5-40	60-95
Gambia	Banjul	90	10
Ghana	Accra, Kumasi, Takoradi and Tamale	10-20	80-90
Guinea	Conakry, Timbi-Madina	70	30
Mali	Bamako	24	76
Mauritania	Nouakchott	15	85
Nigeria	Lagos/Ibadan	5-25	75-95
Sierra Leone	Freetown	80-90	10-20
Togo	Tsévié, Lome	20-30	70-80
India	Delhi, Mumbai, Chennai, Hyderabad and Bengaluru	17	83

4.1.3 Income generation and gross domestic product

Households in developing countries accept urban agriculture as a source of livelihood [5]. Drechsel and Keraita [32] state that two of three urban vegetable farmers in Accra, Ghana had no intentions of leaving the their job even if they were offered regular salaried employment. Amponsah et al. [6] conclude that vegetable farming in Kumasi, Ghana, had become an employment decision for many citizens.

Amponsah et al. [6] conclusion is due to the high incomes the farmers have from agricultural activities within the cities. For instance, Keraita, Jiménez, & Drechsel Keraita2008 concluded that urban farmers in Ghana earned twice as much as their counterparts in rural areas. The increase in income appears to be present in several other cities in the global south as indicated in Table 4.3. The earnings enable the urban farmers to contribute to the national income. For instance, YiZhang and Zhangen [98] found that 2.7 million urban farmers contributed 2% of Shanghai's gross domestic product. Similarly, para grass production and sale in Hyderabad, India contributes an estimated annual income of 4.5 million USD to the city's economy. In Hartford, USA, urban agriculture is estimated to contribute between 4 and 10 million dollars in gross domestic product [71].

TABLE 4.3: Incomes earned by urban vegetable farmers in six cities. [49, 32, 21]

City	Annual income per ha (US$)	Annual GNI per capita (US$)
Nairobi in Kenya	1770	645
Dakar in Senegal	2234	773
Kumasi in Ghana	420-1920	522
Hyderebad in India	830-2800	771
Haroonabad in Pakistan	840	931
Guanajuato in Mexico	1935	7755

The value of urban agriculture to a city's gross domestic product may not be significant when compared to non-agricultural land uses. This could be a reason for the pricing out of agriculture in city land use planning processes. Nevertheless, gross domestic production and other economic indicators underestimate the actual contribution of urban agriculture to city. The approach excludes ecological and social dimensions of urban agriculture. Probably, if these dimensions could be valued and added to the value of urban agriculture, then urban agriculture could be as valuable as other land uses.

4.1.4 Savings and expenditure

It can be observed from Table 4.4 that expense on food in Bangalore, Accra and Nairobi for households who engaged in urban agriculture is below the average of 50–70% for the urban areas [35]. The cities in the northern globe, households spend minimum proportions of their incomes on food, which implies limited contribution of urban agriculture to household savings. The savings may however originate from transportation. The literature indicates that households spend less on transport to obtain or transport food as compared to the other household items. Hamilton et al. [40] had observed that savings occurred as a result of the reduction in transport cost for the urban farmer. The savings result from the amount these farmers would have otherwise incurred if they were to travel to procure the items, they produce themselves. moreover, urban agriculture allows farm produce to be closer to consumers than if the produce is to be supplied by rural farmers. This will therefore reduce travel cost and time to access food items by urban households.

TABLE 4.4: Expenditure pattern of urban agriculture households in some selected cities. Source: World Bank (2013).

Expenditure item	Selected cities		
	Bangalore	Accra	Nairobi
Food	29.2	36.5	39.4
Utilities	16.8	12.3	13.1
Education	11.5	16.7	16.9
Health	10.4	8.2	5.1
Clothes	8.1	7.7	3.0
Shelter	7.0	3.2	18.9
Loan/debt	6.2	1.4	0.4
Transport	4.6	7.9	2.5
Other	3.3	0.8	0.2
Family events	2.1	4.5	0.2
Domestic help	0.7	0.8	0.2

4.2 Urban agriculture and social sustainability of cities

4.2.1 Educational functions

Buehler [22] states that urban agriculture allows a means for learning experiences, youth development and educational programmes. Agricultural projects in California and Philadelphia, USA, are implemented to show the role of urban agriculture in education [19]. These educational services are directed towards teaching the citizens the food-supply-chain of the products they eat, so as to enable them make informed decisions about their food selection.

Moreover, through social networks, urban farmers who have had the benefits of education by research institutions, the knowledge is shared. Urban vegetable farmers in Kumasi in Ghana who have participated in research activities on the World Health Organization's Multiple Barrier Interventions have teach their counterparts who were not part of the training programme

[6, 7]. This highlights the replication effects of such research projects on the larger community.

Urban farmers' earnings from agriculture are used to support their children in school [80]. A study in SriLanka by Gamhewage et al. [37] states that 22% of urban farmers prefer to expend their savings on the education of their children to spending on household possessions. Similarly, in India, some women contribute approximately 23% of their share in household education expenditure from the incomes they earn from urban agricultural activities. Another study in Kampala, Uganda also concluded that urban male farmers and female farmers spend 26% and 12% of their incomes respectively on the fees of their wards in school [21].

However, urban agriculture in the global south is known to stimulate child labour and school deviation [33, 46]. For instance, in Dar-es-Salaam, Tanzania, children engage in urban agriculture at the expense of their education. Similarly, child migrants have been found to be engaged as farm labourers on urban farms in Kumasi, Ghana [8]. In spite of, in these countries, child labour is prohibited. The higher returns from the urban agricultural activities could be an explanation for their attractiveness to children. Children can take advantage of the primary educational policies and programmes in these countries to attend schools [70]. This will enhance the educational functions of urban agriculture towards social sustainability of cities.

4.2.2 Civic engagement

Obach and Tobin [72] and Pole and Gray [79] conclude that people in New York City who were engaged in urban agriculture were more politically engaged and more likely to volunteer in their communities compared to the general population. In the same way, in Dar-es-Salaam in Tanzania, urban farms were used as political gathering spaces in during the 2010 elections. However, Pole and Gray [79] state that the desire for organic foods is the motivation for people to interact with urban farmers other than civic engagement. Obach and Tobin [72] conclude that consumers of urban agricultural products are less likely to engage in charitable giving than the general population. The studies conclude that if the motivation for engaging in urban agriculture is economic, then it is less likely to promote civic engagement.

The economic reasons including household food security, employment and income generation are the main motivations for people's engagement in urban agriculture [8, 50, 46, 99, 5]. Besides, the reasons for agriculture in the cities in the global north are more leaned towards leisure and ecological functions [46, 40]. Urban agriculture's role in civic engagement is more pronounced in the global north than the southern globe.

4.2.3 Safety and security

Urban agriculture provides a significant contribution to the safety of a city. Gardens help to promote energy efficiency in buildings and contribute to fire prevention [44]. Furthermore, clearing an area of bush in a city for agricultural purposes has the potential to eliminate hiding spaces for thieves. Interactions make profound contributions to the social sustainability of cities; as customers, people walking through, people who live nearby, people looking for a day labour job, and more, interact in urban farms.

The University of Pennsylvania's Perelman School of Medicine in Philadelphia executed a study and conclude that greening vacant lots made residents feel significantly safer, and that the greened lots lead to reductions in certain gun crimes in the area [52]. This is consistent with the work of Kuo [53] which stated that the greener a building's surroundings were, the fewer the reported crimes. Kondo conducted a study and stated that there were reductions in crime levels [51]. This could confirm that states that are maintaining and monitoring urban environments in a well-ordered condition may stop further vandalism and escalation into more serious crime. The Urban Food Crisis [88] explains that using blighted lots for urban agricultural purposes reduces crime rates.

Other studies point to the negative side of urban green space [18]. These include encounters with physical danger such as poisonous animals and thorny plants, and the fear of crime [86]. These authors, after a systematic review of literature, point out, however, that factors such as gender and individual's experiences are most influential in evoking fear of crime. This means that the crimes that result from urban agriculture may be imagined from an earlier experience. A fear of crime may therefore be imagined but not real. People should be alerted to thorny plants and poisonous animals to mitigate the adverse effects on neighbourhoods. These measures could enhance the role of urban agriculture in urban safety and security.

4.2.4 Health benefits

Urban agriculture enables an improvement to the health of a city through its contribution to food security [74] and income for farmers and their families to access health care. Community gardens give residents access to fresh fruits and vegetables [55], which are essential to safeguarding their health. From a social point of view, urban agriculture can provide food availability and accessibility. Also, citizens can take advantage of the urban produce to diversify the food intake, which ultimately leads to healthier diets. Research also supports that people who participate or have family members that engage in community gardens "are 3.5 times more likely to consume fruits and vegetables at least 5 times per day than people without a gardening household member" [4]. Urban agriculture helps to reduce malnutrition and promote the general health of the city population.

However, some studies point to the adverse effects of urban agriculture on the health of the cities. These studies stand out the excessive use of agrochemicals [92, 5, 3], which could undermine the health of producers, consumers and the environment, and the use of untreated waste-water for food production [**Ndunda**, 6, 92, 16, 6, 61]. Moreover, the urban agricultural farms can lead to the spread of diseases through mosquitoes and the scavenging animals. Due to these adverse effects, the emphasis of the discourse on the role of urban agriculture in cities' social sustainability should focus on responsible agriculture.

4.3 Urban agriculture and environmental sustainability of cities

4.3.1 Management of emissions

Cities are known for their poor air quality due to GHGs emissions from vehicles and industries [41]. The cities are often with dangerous levels of greenhouse gases. Urban agriculture can manage of these emissions [76]. It is estimated that 711 thousand metric tons of air pollution is removed annually by urban trees [96]. Nevertheless, in high dense populated urban areas, it is difficult to place enough trees to promote air quality; in that situations, rooftop gardens can be implemented.

Yang et al. [96] conclude that the levels of acidic gaseous chemicals decreased by 37%, on a 4 thousand m_2 green roof built in Singapore. Similarly, a study in Toronto, CA, calculated that 7.87 metric tons of air pollutants per year could be removed by 109 ha of green roofs [96]. Planners and city authorities, particularly in the cities in the global north, are making conscious efforts to implement green infrastructure in their city planning processes. Canada, under the Ottawa Green Belt Programme, has acquired 37,000 acres of land for green infrastructural purposes, which includes urban and rural farming [78].

Notwithstanding the urban agriculture ability to manage GHGs emissions, some authors argued that organic urban agriculture can result in the emission of some gases, which may cause negative effects to the environment. Davison and Cape [30] conclude that about 90% of atmospheric ammonia in the US come from organic agriculture, as the ammonia is generated from agricultural activities including soils, fertilisers and domesticated animals waste [77]. The ammonia is transported by winds and returns to the surface by wet or dry processes, which may contribute to the degradation of air quality and visibility, as well as to the atmospheric radiative balance [11].

4.3.2 Waste management

Urban agriculture provides a means to put organic waste to good use. Due to the nutrient-rich properties, Germany encourages the use of solid waste as compost in agriculture. Other European Union member states are developing technologies to collect organic waste and produce compost for agricultural purposes [9]. A New York City study in 2009 stated that more than 130 urban gardens had composting processes, which were merged within the existing city sanitation processes. In the same way, the Governador Valadares provides incentives for composting and reuse of solid waste in urban farms; the City of Cape Town also provides incentives for the use of compost. [44]. The use of compost for crop farming in the cities in the global south has been extensively reported in the conventional literature [5]. These initiatives help to improve environmental sanitation.

Urban agriculture also positively affects the treatment of waste-water. Lydecker and Drechsel [60] conclude that vegetable farms in Accra in Ghana treat the waste-water from about 225 thousand households. The soils serve as filters for the treatment of the waste-water that is used for irrigation purposes. On the other hand, Drechsel and Keraita [32] estimate that urban farms can only absorb and filter a limited amount of the waste-water due to the high degree of pollution. Notwithstanding, agricultural lands have a significant role in reducing the environmental pollution that results from untreated waste-water into the environment. Pollution of the sea and other freshwater resources by untreated waste-water is reduced when it is used for irrigation purposes [58].

In spite of the promising features of urban agriculture in waste management, urban agriculture can lead to the discharge of waste-water into water bodies. Veenhuizen [92] states that urban farms jettison waste-water into open water supplies. As a mitigating strategy, some cities (such as Harare in Zimbabwe) have adopted an approach to filter water from farms through a natural purification process before it enters the city reservoir [54]. Consequently, a safe and responsible urban agriculture is required to offset its negative effects on city waste management

4.3.3 Energy efficiency

Cities tend to be warmer than their surroundings due to their high energy consumption [41]. Urban heat effects cause cities to have daytime surface temperatures of up to 10°C higher than the rural areas around them [94]. Urban agriculture can contribute to the reduction of the urban heat island effects by providing shade and enhanced evapo-transpiration, and by providing cooler temperatures with less smog. The University of Manchester concluded that a 10% increase in the amount of green, possibly through urban agriculture in cities, can reduce surface temperatures in urban environments by up to 4°C [38]. Shading by vegetation redistribute incoming solar radiation and diffuses light reflected from nearby urban surfaces that would otherwise be reflected as heat by urban surfaces [82]. Green roofs can increase evapo-transpiration while reducing the energy demand for space climate conditioning [81]. Green roofs can decrease the energy required to heat and cool buildings [2]. The location of farms in cities also reduces the need to transport goods such as food to markets and farm inputs to farms.

In spite of the ability of urban agriculture to manage energy, the intensive use of technology may intensify the energy use in the cities. A study conducted in Yuma, Arizona, USA compared the energy requirements of hydroponics and conventional agriculture. The authors concluded that hydroponics offered 11 ± 1.7 times higher yields but required 82 ± 11 times more energy compared to conventionally produced lettuce [14]. Therefore, urban agriculture helps to manage energy use in the cities, some technologies have the potential to increase energy use in the city. Focus on renewable energy use by these technologies could help to manage emissions.

4.3.4 Organic farming in percentage of total agricultural area

Agriculture provides food, however, it is a major contributor to greenhouse gases, biodiversity loss, agro-chemical pollution, and soil degradation [28]. Conventional agriculture brought up the adopting alternative farming systems that are more environmentally friendly (Organic agriculture). In Germany, there have been new developments to heavily promote organic farming and the banning of pesticide use in public gardens. There are more than 1.4 million organised allotment gardens, which occupy an area of nearly 47,000 ha [44].

In New York City, organic farming reduces the environmental and economic costs of dealing with the city's waste stream by using waste as compost. Also, in Rosario in Argentina, organic waste is converted into bio-fertiliser and reused. Similarly, El Alto, Bolivia recycles organic waste material from the gardens to feed and raise guinea pigs [44]. The adoption of a labour intensive production in urban agriculture results in the consumption of less crude fuel by machinery for extracting, processing and transporting fossil fuel based fertilisers [29]. However, the idea of using waste for compost may escalate into untenable negative effects if not managed well. The odour that may be created from the waste from animals [39] may negatively affect the role of urban agriculture contributing to organic farming.

5 Garden Gem

Plentiful, healthy, economic and safe food for the entire planet is a topic to be held in our minds for the following years. Food safety and security are the main challenges to be discussed along with the confrontations against climatic change. At least 55% of the world's population already lives in urban areas, and this number is expected to rise to 65% by 2050. (FAO, 2019) Nearly 80% of all food produced is consumed in these urban areas and, according to information of the Food and Agriculture Organization of the United Nations, 60% of irrigated and 35% of rainfed croplands are within a 20 km radius of urban agglomerations. (FAO, 2019) Additionally, almost one third of all food produced for humans is lost into waste that comprises more than 50% of all municipal waste. (FAO, 2019) Finally, it is important to point out that in low-income countries, food expenditures can take up to two thirds of the total household. (FAO, 2019) Food policies require training citizens about new lifestyles. The training purpose is to incentivize awareness to address sustainable food safety and security. (Sandrini, 2014) The lifestyle of human kind shall be amended, particularly in regards of our food supply chain, from the farming, distribution to the end consumer. Through food education, the system players (consumers and producers) are trained. A new lifestyle will also have an environmental impact related to transportation and distribution. (Sandrini, 2014)

It is important to conserve farming land, especially in areas already subject to strong urbanization. GardenGem's purpose is to be a tool for urban gardeners, researchers and citizens for food education and urban agriculture.

5.1 Impact on the Economic Dimension

Urban gardening has been part of the human economic activities since the emergence of cites as the urban phenomena developed. (Calvet-Mir, L., &

March, H., 2019) A study carried out by Calvet-Mir, L. & March, H. established the importance of urban gardening as a response to financial crisis and their strong correlation to community resilience against war and other adversities. Populations of growing poverty rates in cities are also impacted by the development of urban gardens. Self-production or self-sufficiency of food are directly related to food security during economic crisis and shortages. Helping build self-sufficient cities improves the health and quality of food and rises awareness around local produce food sovereignty.

As detailed in Section 4.1, GardenGem takes this perspective into account, trying to aim towards an economically sustainable activity that can provide better food prices and optimal operational costs to any user of the application.

5.2 Impact on the Social Dimension

Urban gardening comes as a response to changing social and political circumstances. There have been numerous initiatives to promote their practice during conflicts and economic crisis to tackle food distribution problems during specific historical moments. These factors have an important effect shaping the form, function and culture of urban gardens and their members [23]. Since the last century, we have witnessed a growing institutional recognition of urban gardening, through national and local legislation in many countries, including Mexico.

Urban gardening portrays emancipatory and alternative views about the urban development and social relations. There is evidence of urban gardens being used to protest against political corruption, empowering the people and appealing to citizen responsibility to overcome any crisis [25]. Social entrepreneurship and social innovation are strongly related to urban gardening since it is subject of continuous improvement mainly due to the huge positive impact it has in people's lives. It has been demonstrated that urban gardens have the effect of strengthening community ties, enabling intercultural exchanges, facilitating community building as and enhancing social cohesion where the garden is located [23].

The GardenGem team is making research on these aspects to develop the right campaign for the encouragement of urban agriculture. We are working to find the correct approach towards people and government for incentivization and support. Section 4.2 lists the social impact that Garden Gem is targeting.

5.3 Impact on the Environmental Dimension

Human beings have been altering their environment since the beginning of their existence; in fact, this specific trait is the most concluding evidence of human presence in any place or time. Urban planning is the practice of spatial arrangement of urban areas [25]. These arrangements unequivocally have an impact on the environment, thus the planification of cities must always consider alternatives for the best land distribution to allow human development without strangling itself by damaging its resources. Urban agriculture enhances the diversity and distribution of food and non-food products through processes that reuse human and material resources. This has a positive impact in and around the urban area supplying products and services to the same area in return [20].

We want to prepare people with tools that empower them to take their environmental impact on their hands and start acting positively in the right direction. GardenGem is meant to improve the caring of the environment in a sustainable and practical way, by impacting the processes in Section 4.3.

5.4 Garden Gem Objectives

GardenGem is a mobile application that will help urban gardeners by assisting them in the correct development and maintenance of their urban gardens. Garden Gem's will provide the information required to find compatible food plants with similar care and know the number of plants that can be placed within a given land area. Additionally, it will offer an in-app store to facilitate the purchase of materials and supplies for the optimal development of their urban garden. Further into the future, the app will feature a community intercommunication between urban gardeners to allow sharing and trading. The compatibility with other technologies as the Food Computer from the Open Agriculture Iniciative from the MIT will make this application even more useful for the automation of urban garden production.

Economical goal: To enable the average citizen, and local community to grow vegetables locally in order to save money and create a possible source of income.

Social goal: To promote social integration and combat poverty by the creation of urban garden communities based on participation.

Environmental goal: To enhance the diversity and distribution of food products through processes that reuse resources in a sustainable and local way.

5.4.1 Monetization

The monetization of this product will be based in the in-app store where users and suppliers will receive small fees for each buy. One product that is expected to become a popular purchase is the kit for the construction of a Food Computer, since all the manuals and designs are openly available in the Open Agriculture Initiative. These fees will be the main source of income in the beginning. Once the community functionality is ready, trading fees between gardeners and direct consumers or distributors will support the application and its growth.

5.5 Garden Gem Results

5.5.1 Development of the mobile application

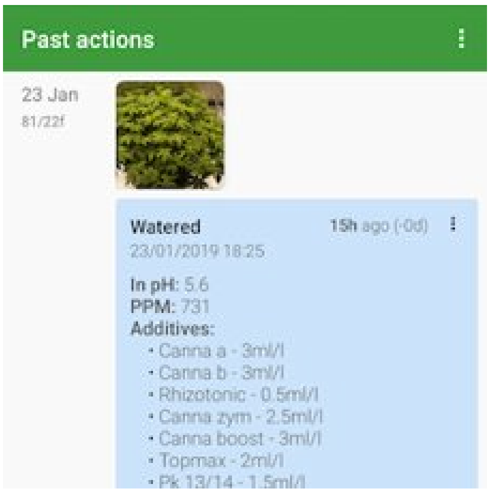

FIGURE 5.1: Record of the actions done to a given plant

The application can record data about growing plants in order to monitor the growing conditions and make the plants grow better by identify potential

FIGURE 5.2: Feeding Amnesia X OG, characteristics

issues during the growing process. The application is also concentrating in the three pillars of sustainability focusing on its impact in the improvement of life standards for any user of our application according to the economic, environmental and social perspectives that were previously described in this project.

Figures 5.1, 5.2 and 5.3 show the final application running on an android device. In Figure 1 the actions that have been already done to the plant are recorded and showed. Figure 2 shows the proper characteristics needed for feeding Amnesia X OG. Finally, figure 3 shows all the current plants that are intended to growth in the best possible way.

According to the surveys performed to people from multiple backgrounds, the application received an approval rate of above 95%. More than 60% of the people who participated on the survey were already considering urban gardens before checking our app, and more than 90% thought it would be useful. The complete results of this survey are presented in the annex section of this document.

FIGURE 5.3: All plants

6 Conclusion

The complexities involved in the development of sustainable cities cannot be ignored by researchers and city authorities. The idea of sustainable city has over the years been simplified. Researchers and authorities focus mostly on the multi-functional dimensions of sustainability and overlook the complementary and conflicting roles of these functions. This report, which seeks to determine the relation between urban agriculture and sustainable cities, and a educational contribution through a mobile application (Garden Gem) has addressed various sustainable indicators in the sustainable city discourse. This report is based on a framework that takes into consideration the sustainability of cities from the economic, social and environmental sustainability dimensions.

The results show that the social, economic and environmental functions of urban agriculture have both positive and some negative outcomes. Moreover, the survey shows that more people are willing to engage in urban agricultural activities with the help of a mobile application, which provides basic agricultural educational information with the ability to track the produce progress. The report's analyses confirm, the benefits of urban agriculture especially the ecological and social dimensions have been ignored. Researchers such as Veenhuizen [92] and Yamusa [3] argue that the contributions of urban agriculture to sustainable cities have been overestimated. Nevertheless, the analyses indicate that urban agriculture can drive development countries to sustainability.

Cities with large vacant lands, urban agriculture should be implemented with responsible integrations into the city land zoning planning. In the developed countries, ecologically sensitive regions can be protected to provide spaces for urban farming practices to reinforce the ecological functions. Nevertheless, in developing countries such as Ghana, urban agriculture can help to protect the ecologically sensitive areas. Responsible agriculture is required for the sustainable cities, which will aims to the protection of the ecological functions of urban gardens.

GardenGem will be a functional "plant data base" to allow the users to search over 30,000+ plants of the world over multiple criteria and get up-to-date information about their specific requirements for successful culture. GardenGem aims to become the most reliable resource for food education and urban agriculture development. After having provided the information and "know how" to the users, we will be adding hardware on sale for the physical improvement of their urban gardens. For this step, we will be contacting external providers to announce their products on our application and make them compatible with our technology. One of the main projects we are to be involved in is OpenAg Initiative from the MIT. The Personal Food Computer (PFC) they have developed has all the hardware and software design necessary for the automation of crops. (pfc_edu_3.0 OpenAg, 2019) Together with GardenGem, this computer may be more easily operated by any user. Talking with authorities to provide legal advice and permits in the development of this gardens in public areas is another important task to be done for a larger positive impact in local communities.

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A The Green City Index

TABLE A.1: Supplementary Table: The Green City Index. Source: (Economist Intelligence Unit 2009; Venkatesh 2014)

Categories	Indicators	Description	Normalisation technique
1. Environmental governance	1.1 Green action plan 1.2. Green management 1.3. Public participation in green policy	1.1.1 An assessment of the ambitiousness and comprehensiveness of strategies to improve and monitor environmental performance. 1.2.1 An assessment of the management of environmental issues and commitment to achieving international environmental standards. 1.3.1 An assessment of the extent to which citizens may participate in environmental decision-making.	1.1.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10. 1.2.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10. 1.3.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.

Categories	Indicators	Description	Normalisation technique
2. Carbon dioxide	2.1 Emissions 2.2 Intensity 2.3 Reduction strategy	2.1.1 Total CO2 emissions, in tonnes per head. 2.2.1 Total CO2 emissions, in grams per unit of real GDP (2000 base year). 2.3.1 An assessment of the ambitiousness of CO2 emissions reduction strategy.	2.1.1 Min-max. 2.2.2 Min-max; lower benchmark of 1,000 grams inserted to prevent outliers. 2.3.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.
3. Buildings	3.1 Energy consumption of residential buildings 3.2 Energy-efficient building standards 3.3 Energy-efficient building initiatives	3.1.1 Total final energy consumption in the residential sector, per square metre of residential floor space. 3.2.1 An assessment the extensiveness of cities' energy efficiency standards for buildings. 3.3.1 An assessment of the extensiveness of efforts to promote energy efficiency of buildings.	3.1.2 Min-max. 3.2.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10. 3.3.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.
4. Transport	4.1 Use of non-car transport 4.2 Size of non-car transport network 4.3 Green transport promotion 4.4 Congestion reduction policies	4.1.1 The total percentage of the working population travelling to work on public transport, by bicycle and by foot. 4.2.1 Length of cycling lanes and the public transport network, in km per square metre of city area. 4.3.1 An assessment of the extensiveness of efforts to increase the use of cleaner transport. 4.4.1 An assessment of efforts to reduce vehicle traffic within the city.	4.1.2 Converted to a scale of 0 to 10. 4.2.2 Min-max. Upper benchmarks of 4 km/km2 and5 km/km2 inserted to prevent outliers. 4.3.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10. 4.4.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.

Categories	Indicators	Description	Normalisation technique
5. Water	5.1 Water consumption 5.2 Water system leakage 5.3 Wastewater treatment 5.4 Water efficiency and treatment policies	5.1.1 Total annual water consumption, in cubic metres per head. 5.2.1 Percentage of water lost in the water distribution system. 5.3.1 Percentage of dwellings connected to the sewage system. 5.4.1 An assessment of the comprehensiveness of measures to improve the efficiency of water usage and the treatment of wastewater.	5.1.2 Min-max. 5.2.2 Scored against an upper target of 5%. 5.3.2 Scored against an upper benchmark of 100% and a lower benchmark of 80%. 5.4.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.
6. Waste and land use	6.1 Municipal waste production 6.2 Waste recycling 6.3 Waste reduction policies 6.4 Green land use policies	6.1.1 Total annual municipal waste collected, in kg per head. 6.2.1 Percentage of municipal waste recycled. 6.3.1 An assessment of the extensiveness of measures to reduce the overall production of waste, and to recycle and reuse waste. 6.4.1 An assessment of the comprehensiveness of policies to contain the urban sprawl and promote the availability of green spaces.	6.1.2 Scored against an upper benchmark of 300 kg (EU target). A lower benchmark of 1,000 kg inserted to prevent outliers. 6.2.2 Scored against an upper benchmark of 50% (EU target). 6.3.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10. 6.4.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.

Categories	Indicators	Description	Normalisation technique
7. Energy	7.1 Consumption 7.2 Intensity 7.3 Renewable energy consumption 7.4 Clean and efficient energy policies	7.1.1 Total final energy consumption, in gigajoules per head. 7.2.1Total final energy consumption, in megajoules per unit of real GDP (in euros, base year 2000). 7.3.1 The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption, in terajoules. 7.4.1 An assessment of the extensiveness of policies promoting the use of clean and efficient energy.	7.1.2 Min-max. 7.2.2 Min-max; lower benchmark of 8MJ/€GDP inserted to prevent outliers. 7.3.2 Scored against an upper benchmark of 20% (EU target). 7.4.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.
8. Air quality	8.1 Nitrogen dioxide 8.2 Ozone 8.3 Particulate Matter (PM) 8.4 Sulphur dioxide 8.5 Clean air policies	8.1.1 Annual daily mean of NO2 emissions. 8.2.1 Annual daily mean of O3 emissions. 8.3.1 Annual daily mean of PM10 emissions. 8.4.1 Annual daily mean of SO2 emissions. 8.5.1 An assessment of the extensiveness of policies to improve air quality.	8.1.2 Scored against a lower benchmark of 40 ug/m3 (EU target). 8.2.2 Scored against a lower benchmark of 120 ug/m3 (EU target). 8.3.2 Scored against a lower benchmark of 50 ug/m3 (EU target). 8.4.2 Scored against a lower benchmark of 40 ug/m3 (EU target). 8.5.2 Scored by Economist Intelligence Unit analysts on a scale of 0 to 10.

B Global City Indicators Facility

TABLE B.1: Supplementary Table: Global City Indicators Facility. Source: (ISO/IEC JTC 1 Information Technology 2015; McCarney 2009)

Categories	Indicators		Supporting Indicators
City Services	Education	Student/teacher ratio Percentage	Percentage of school-aged population enrolled in schools
		Percentage of students completing primary and secondary education: survival rate	Percentage of male school-aged population enrolled in schools
		Percentage of students completing primary education	Percentage of female school-aged population enrolled in schools
		Percentage of students completing secondary education	

Categories	Indicators		Supporting Indicators
City Services	Fire and Emergency Response	Number of fire fighters per 100,000 population	Response time for fire department from initial call
		Number of fire related deaths per 100,000 population	
	Health	Number of in-patient hospital beds per 100,000 population	Number of nursing and midwifery personnel per 100,000 population
		Number of physicians per 100,000 population	
		Average life expectancy	
		Under age five mortality per 1,000 live births	
	Recreation		Square metres of public indoor recreation space per capita
			Square metres of public outdoor recreation space per capita
	Safety	Number of police officers per 100,000 population	Violent crime rate per 100,000 population
		Number of homicides per 100,000 population	

Categories	Indicators		Supporting Indicators
City Services	Solid waste	Percentage of city population with regular solid waste collection	Percentage of the city’s solid waste that is disposed of in an incinerator
		Percentage of city’s solid waste that is recycled	Percentage of the city’s solid waste that is burned openly
			Percentage of the city’s solid waste that is disposed of in an open dump
			Percentage of the city’s solid waste that is disposed of in a sanitary landfill
			Percentage of the city’s solid waste that is disposed of by other means
	Transportation	Km of high capacity public transit system per 100,000 population	Number of two-wheel motorized vehicles per capita
		Km of light passenger transit system per 100,000 population	Commercial Air Connectivity (number of non- stop commercial air destinations)
		Number of personal automobiles per capita	Transportation fatalities per 100,000 population
			Annual number of public transit trips per capita
	Wastewater	Percentage of city population served by	Percentage of the city’s wastewater receiving primary treatment
		Percentage of the city’s wastewater that has received no treatment	Percentage of the city’s wastewater receiving secondary treatment
			Percentage of the city’s wastewater receiving tertiary treatment

Categories	Indicators		Supporting Indicators
City Services	Water	Percentage of city population with potable water supply ser- vice	Total water consumption per capita (litres/ day)
		Domestic water consumption per capita (litres/day)	Percentage of water loss
		Percentage of city population with sustainable access to an improved water source	Average annual hours of water service interruption per household
	Energy	Percentage of city population	Total electrical use per capita (kWh/year) with authorized electrical service
		Total residential electrical use per capita (kWh/year)	The average number of electrical interruptions per customer per year
			Average length of electrical interruptions (in hours)
	Finance	Debt service ratio (debt service expenditure as a percent of a municipality's own-source revenue)	Tax collected as percentage of tax billed
			Own-source revenue as a percentage of total revenues
			Capital spending as a percentage of total expenditures

Categories	Indicators		Supporting Indicators
City Services	Governance		Percentage of women employed in the city government workforce
	Urban Planning	Jobs/Housing ratio	Areal size of informal settlements as a percent of city area Green area (hectares) per 100,000 population
Quality of Life	Civic Engagement	Voter participation in last municipal election (as a percent of eligible voters)	Citizen's representation: number of local officials elected to office per 100,000 population
	Economy		Percentage of persons in full time employment
	Culture		Percentage of jobs in the cultural sector
	Environment	PM10 concentration	Greenhouse gas emissions measured in tonnes per capita

Categories	Indicators		Supporting Indicators
Quality of Life	Shelter	Percentage of city population living in slums	Percentage of households that exist without registered legal titles
			Number of homeless people per 100,000 population
	Social Equity		Percentage of city population living in poverty
	Technology and Innovation	Number of internet connections per 100,000 population	Number of new patents per 100,000 per year
			Number of higher education degrees per 100,000
			Number of telephone connections (landlines and cell phones) per 100,000 population
			Number of landline phone connections per 100,000 population
			Number of cell phone connections per 100,000 population

C Global Compact Cities Circles of Sustainability

TABLE C.1: Supplementary Table: Global Compact Cities Circles of Sustainability. Source: KPMG International (2016) (http://www.circlesofsustainability.org/circles-overview/profile-circles/)

Category	Indicators	Sub-indicators
Economics	Production & Resourcing	Prosperity and Resilience
		Manufacture and Fabrication
		Extraction and Harvesting
		Art and Craft
		Design and Innovation
		Human and Physical Resources
		Monitoring and Reflection
	Exchange & Transfer	Reciprocity and Mutuality
		Goods and Services
		Finance and Taxes
		Trade and Tourism
		Aid and Remittances
		Debt and Liability
		Monitoring and Reflection
	Accounting & Regulation	Transparency and Fairness
		Finance and Money
		Goods and Services
		Land and Property
		Labour and Employment
		Taxes and Levies
		Monitoring and Reflection

Category	Indicators	Sub-indicators
Economics	Consumption & Use	Appropriate Use and Re-use Food and Drink Goods and Services Water and Electricity Petroleum and Metals Promotion and Dissemination Monitoring and Reflection
	Labour & Welfare	Livelihoods and Work Connection and Vocation Participation and Equity Capacity and Productivity Health and Safety Care and Support Monitoring and Reflection
	Technology & Infrastructure	Appropriateness and Robustness Communications and Information Transport and Movement Construction and Building Education and Training Medicine and Health Treatment Monitoring and Reflection
	Wealth & Distribution	Accumulation and Mobilization Social Wealth and Heritage Wages and Income Housing and Subsistence Equity and Inclusion Re-distribution and Apportionment Monitoring and Reflection
Ecology	Water & Air	Vitality and Viability Water Quality and Potability Air Quality and Respiration Climate and Temperature Greenhouse Gases and Carbon Adaptation and Mitigation Processes Monitoring and Reflection
	Flora & Fauna	Complexity and Resilience Biodiversity and Ecosystem Diversity Plants and Insects Trees and Shrubs Wild Animals and Birds Domestic Animals and Species Relations Monitoring and Reflection

Category	Indicators	Sub-indicators
Ecology	Habitat & Settlements	Topography and Liveability Original Habitat and Native Vegetation Parklands and Reserves Land-use and Building Abode and Housing Maintenance and Retrofitting Monitoring and Reflection
	Built-Form & Transport	Orientation and Spread Proximity and Access Mass Transit and Public Transport Motorized Transport and Roads Non-motorized Transport and Walking Paths Seaports and Airports Monitoring and Reflection
	Embodiment & Food	Physical Health and Vitality Reproduction and Mortality Exercise and Fitness Hygiene and Diet Nutrition and Nourishment Agriculture and Husbandry Monitoring and Evaluation
	Emission & Waste	Pollution and Contamination Hard-waste and Rubbish Sewerage and Sanitation Drainage and Effluence Processing and Composting Recycling and Re-use Monitoring and Evaluation
Politics	Organization & Governance	Legitimacy and Respect Leadership and Agency Planning and Vision Administration and Bureaucracy Authority and Sovereignty Transparency and Clarity Monitoring and Reflection
	Law & Justice	Rights and Rules Order and Civility Obligations and Responsibilities Impartiality and Equality Fairness and Prudence Judgement and Penalty Monitoring and Reflection

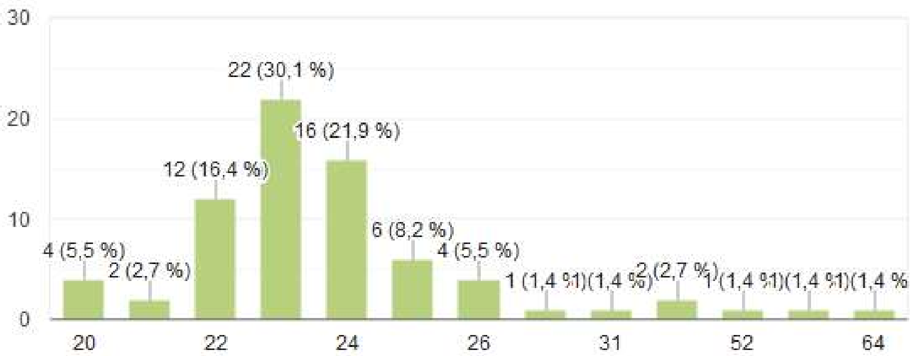
Category	Indicators	Sub-indicators
Politics	Communication & Critique	Interchange and Expression News and Information Accessibility and Openness Opinion and Analysis Dissent and Protest Privacy and Respect Monitoring and Reflection
	Representation & Negotiation	Agency and Advocacy Participation and Inclusion Democracy and Liberty Access and Consultation Civility and Comity Contestation and Standing Monitoring and Reflection
	Security & Accord	Human Security and Defence Safety and Support Personal and Domestic Security Protection and Shelter Refuge and Sanctuary Insurance and Assurance Monitoring and Reflection
	Dialogue & Reconciliation	Process and Recognition Truth and Verity Mediation and Intercession Trust and Faith Remembrance and Redemption Reception and Hospitality Monitoring and Reflection
	Ethics & Accountability	Principles and Protocols Obligation and Responsibility Integrity and Virtue Observance and Visibility Prescription and Contention Acquittal and Consequence Monitoring and Reflection
Culture	Identity & Engagement	Diversity and Difference Belonging and Community Ethnicity and Language Religion and Faith Friendship and Affinity Home and Place Monitoring and Reflection

Category	Indicators	Sub-indicators
Culture	Creativity & Recreation	Aesthetics and Design
		Performance and Representation
		Innovation and Adaptation
		Celebrations and Festivals
		Sport and Play
		Leisure and Relaxation
		Monitoring and Reflection
	Memory & Projection	Tradition and Authenticity
		Heritage and Inheritance
		History and Records
		Indigeneity and Custom
		Imagination and Hope
		Inspiration and Vision
		Monitoring and Reflection
	Belief & Ideas	Knowledge and Interpretation
		Ideologies and Imaginaries
		Reason and Rationalization
		Religiosity and Spirituality
		Rituals and Symbols
		Emotions and Passions
		Monitoring and Reflection
	Gender & Generations	Equality and Respect
		Sexuality and Desire
		Family and Kinship
		Birth and Babyhood
		Childhood and Youth
		Mortality and Care
		Monitoring and Reflection
	Enquiry & Learning	Curiosity and Discovery
		Deliberation and Debate
		Research and Application
		Teaching and Training
		Writing and Codification
		Meditation and Reflexivity
		Monitoring and Reflection
	Health & Wellbeing	Integrity and Autonomy
		Bodies and Corporeal Knowledge
		Mental Health and Pleasure
		Care and Comfort
		Inclusion and Participation
		Cuisine and Emotional Nourishment
		Monitoring and Reflection

A survey was applied to validate the direction of our project and the interest of the general population on our proposed solution. Here we show the results:

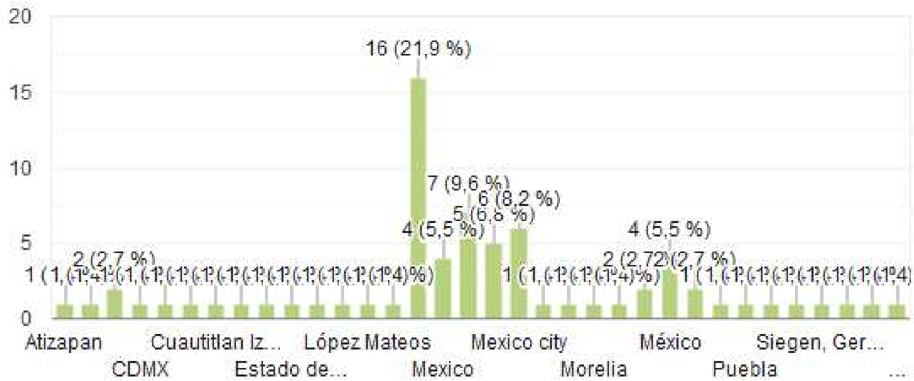
How old are you?

73 respuestas



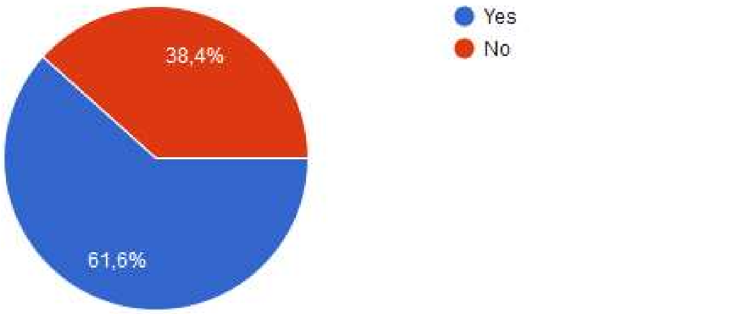
In which city do you live?

73 respuestas



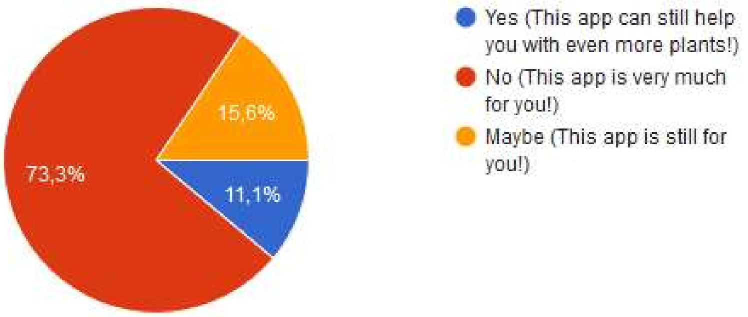
Have you ever considered practicing urban gardening to produce your own food?

73 respuestas



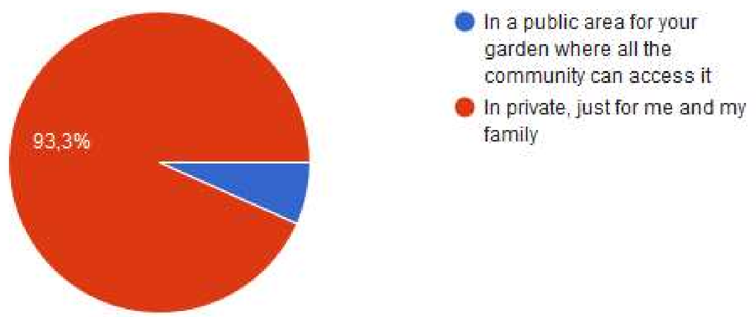
Do you know all the conditions requiered to plant the plants you are interested in?

45 respuestas



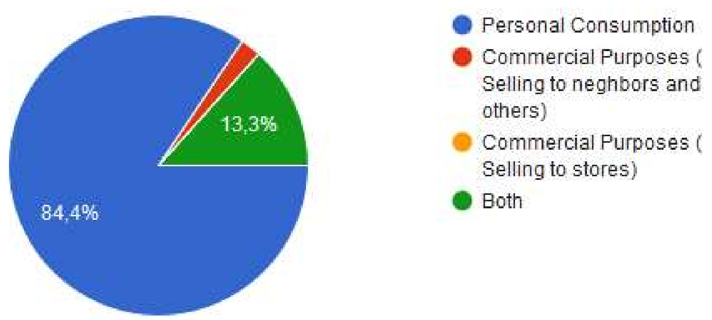
Where would you build your garden?

45 respuestas



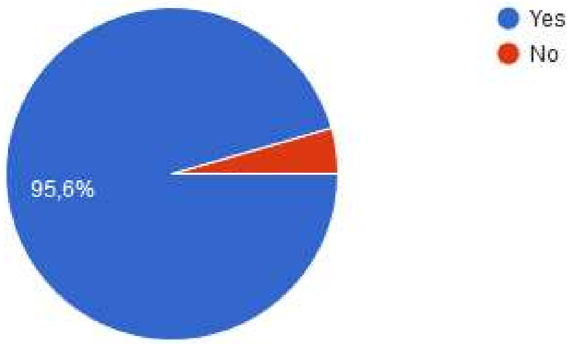
Would you harvest forpersonal consumption or would you sell your crops to neghbors and others?

45 respuestas



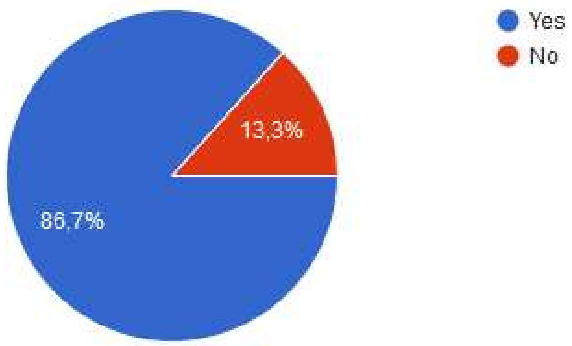
Would you like to have an application where you can consult all the requirements you need for your plants and schedule its lighting and watering, for example?

45 respuestas



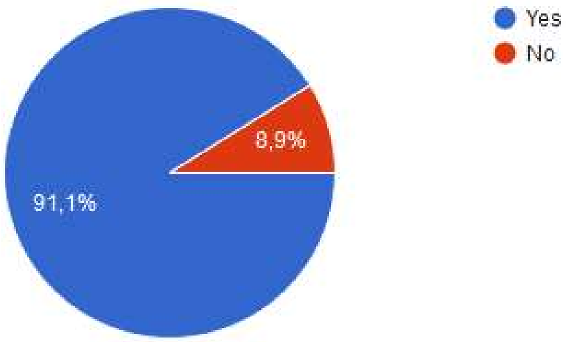
Would you find it useful to access a store on this app to compare prices and buy anything you need receiving it in your home or desired address?

45 respuestas



Would you support this application being compatible with a Food Computer that counts with the sensors and actuators to automate your crops?

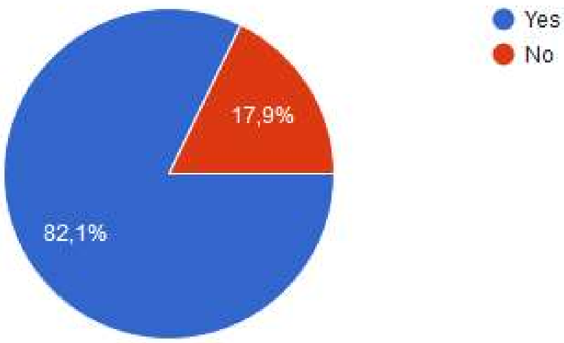
45 respuestas



Let us try to convince you that it is a good idea!

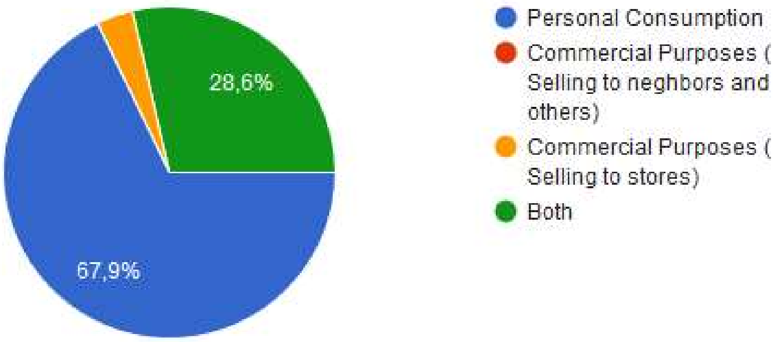
Do you consider there is an oportunity to protect your economy by having your own crops?

28 respuestas



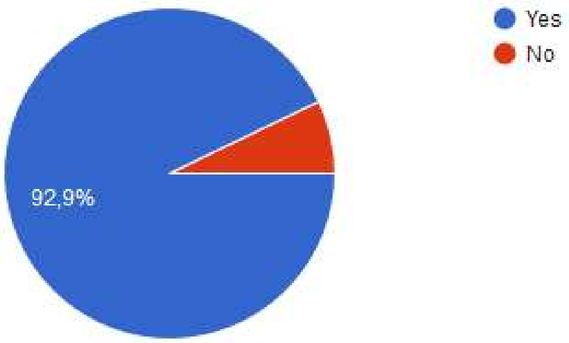
If you decided to have an urban garden would you use it for personal consumption or would you sell your crops to neghbors and others?

28 respuestas



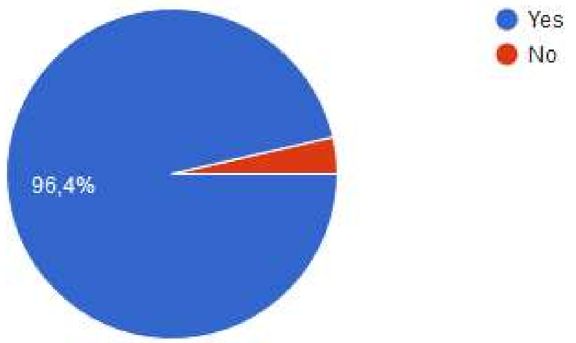
Would you like to have an application where you can consult all the requirements you need for your plants and schedule its lighting and watering, for example?

28 respuestas



Would you find it useful to access a store on this app to compare prices and buy anything you need receiving it in your home or desired address?

28 respuestas



Would you support this application being compatible with a Food Computer that counts with the sensors and actuators to automate your crops?

28 respuestas