The Use of Organic Waste from Animals and Plants as Important Input to Urban Agriculture in México City

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Abstract

Mexico City is a cosmopolitan city and is the country's financial center, also have agricultural activities as result of the historic development of the Great Tenochtitlan. In 1950 began the modernization of this city and seemed to agricultural production systems disappear, but each of the existing systems had to be attached to the new rules of the city. At present agricultural production systems are characterized by "minifundio" (restricted ownership of land), spaces defined by urban development and the use of industrial waste materials. Production in this city can be characterized into 3 systems (Urban, Sub-Urban and Peri-Urban), there is also east of Mexico City's the "Central de Abasto", where it sold more than 40% of national agricultural production are generated daily and 11.400 tons of garbage (at least). An important and positive aspect of the type of models described in this study is the use of organic waste products as inputs.

Keywords: Cows, recycling, peri-urban, urban agriculture

1. Introduction

The Valley of Mexico is a closed space with an extension of approximately 9600 km^2, in the centre of which is Mexico City and its metropolitan area are located. Together they make up what considered one of the most densely populated cities in the world with a paved surface of 1728 km^2, a population of 24 million inhabitants including a stratum of the population characterized as "floating" (INEGI, 2010) and an estimated 2´744,441 dwellings which combined give it the character of a megalopolis.An activity of great importance in the Valley of Mexico was, for a long time, agriculture, which constituted the economic base of the Pre-Hispanic societies that established themselves there, using different forms of production and repertories of domesticated plants adapted to the environment.

The beginning of the colonial period, considered by some authors as the importation of a western model, brought with it important changes in the way of life of the valley's inhabitants. One of these was the role of agriculture which shared its importance with the blossoming mining activity. During the following centuries, the economic importance of agriculture in the city gradually diminished especially from the beginning of the 20^{th} century onwards, first as a consequence of the industrial revolution and later, in the early 1950's, when the country took up the offer of development and modernization. The remaining agriculture was atomized due to the displacement of agricultural zones by buildings and the loss of the labour force that looked for permanent, better paid jobs.

Despite this, the strong cultural ties of the local and migrant population with Pre-Hispanic Mexico created the conditions for a new urban agriculture which assimilated waste products from the city in order to convert them into inputs for production. This study analyzes agriculture in the context of urbanization in order to conceptualize the structural bases of an urban agriculture that assimilated the city's organic waste as a source of organic matter and nutrients and also its prospects in the face of the need to encourage this activity in terms of sustainability.

2. Agro-Ecological Characteristics of the Valley of Mexico

The agrological scenario in which agriculture was carried out in the Valley of Mexico included the concurrence of a series of factors that favoured production such as its altitude above sea-level (2429 m).

Most of the rivers and streams such as Churubusco, La Piedad and Consulado, have been covered over. The only natural lake is that of Xochimilco which is made up of a network of canals which are partly feed with recycled water (Aguilar, 2008).

The agricultural areas are extensive in the south producing: lucerne (alfalfa), oats, maize, beans, peas, carrots, amaranth, vegetable nopal and flowers amongst others. The most important fauna include sparrows, doves, magpies and hummingbirds. Tree squirrels have proliferated in the city's parks and woodlands while in the mountains there are coyotes, mountain cats, skunks, teporingo (volcano rabbit, *Romerolagusdiazi*), cacomixtle (*Bassariscussumichrasti*), rattle snakes, falcons, eagles, ducks, widgeon, garrablanco y gris, charol, toads, frogs and axolotl (Alcérreca, 1988)

2.1 City Agriculture as a Concept

Agriculture in Mexico City is not a new activity in the urban context to the contrary, it represents one of the productive processes that give coherence to the Valley of Mexico the origins of which date back to the founding of the Great Tenochtitlán as the social and ceremonial centre of greatest importance in the region (Rojas 1990).
The new values of western society, related to its preoccupation with health and beauty, has contributed to the development of ancestral crops such as nopal-vegetable. Just as agricultural production has found new production and commercialization alternatives, new uses have been found for the garbage of the great metropolis as animal feedstuff (Losada et al., 1996a), and later the waste from these animals is used in the agricultural zones on the outskirts of the city (Losada et al., 1996b). Thus, the contribution of nutrients in the soil that permits us identify a system of agricultural-livestock production, brings the city closer to a proposal for sustainability in urban areas (Meul et al., 2009).

Urban agriculture (UA) has been defined by a number of authors as all forms of agriculture for the production of food and goods by those people who benefit from the service infrastructure of human urban concentrations as well as having access to prime materials. The characteristics of city agriculture in the environs of the MZMC include (Shiere et al., 2002).

3. Spaces where Urban Agriculture is Carriedout and Organic Waste Materials are Produced and Used

From the point of view of the use of physical space, urban agriculture has developed in three spaces defined as urban, sub-urban and peri-urban (Losada et al., 2011a), and differentiated by the physical place in which the activity is carried out, the type of population, the way the activity is structured in the family environment, the inputs, products and environmental management of waste materials that favour the presence of different production systems.

The different characteristics of spaces where urban agriculture is carried out are the result of the density of buildings, streets, open spaces and some particular aspects such as the presence of bodies of water or woodlands that are included in Table 1.

3.1 Urban Space

The excessive growth of the urban area that has occurred in Mexico City over the past fifty years caused the transformation of the green spaces into grey environments where the city's villages and farming communities were encircled by the new urban surroundings. Of the Federal District's 16 delegations, 9 have been considered as "urban" spaces, which means that the acquisition of a new asphalt culture, the car, cement and pollution have become part of metropolitan daily life (Cortés et al., 2011).

3.2 Sub-Urban Space

The sub-urban model per excellence is the Pre-Hispanic chinampa which has survived the onslaught of urban expansion (Wigle, 2010). The chinampa, made up of a small parcel of land adapted for agriculture. It is surrounded by water which is used for the production of vegetables, flowers and ornamental plants.

The geographical distribution of this form of production is one in which the classical chinampa makes use of the spaces surrounded by water for agriculture and inputs for livestock (grasses), while on the banks (villages, barrios) an association of agriculture and livestock is found (Soriano and Losada, 1993).

The presence of maize, alone or in association with squash, vegetables and flowers also occurs in chinampa agriculture (Losada et al., 2011b). In animal production, the prevailing systems are small-scale and meat production in stables, backyard production of hens, turkeys, fighting cocks, pigs, rabbits, sheep and songbirds. In the sub-urban space there are also draught animals (mules and horses) used to draw carts for transporting bovine excreta to the small-holdings as well as for human transport and the amusement of visiting local tourists at weekends.

3.3 Peri-Urban Space

In the peri-urban space there are two production models: the terrace in the southeast of the city and valley agriculture on the periphery, including Teotihuacán. The terrace is an extension of land above the mean level where agricultural and livestock activities are carried out. In the terraced areas there are different production spaces: the space in the village, concentrating on animal production (milk and meat in stables) and draught animals (mules, donkeys and horses). The other zone is known as the backyard where there are hens, turkeys, ducks, rabbits, pigs and songbirds and the family orchard for the production of vegetables, fruit trees, condiments, medicinal and ritual plants as well as ornamental plants (Losada et al., 2000).

4. Production, Collection and Types of Waste in Mexico City

Rubbish is a side product of technology and urbanization that can be considered a residue (organic or inorganic/non-organic) that is discarded as an input for any given process or Man's daily life. Conservative sources give an estimated production of 11,400 t d^{-1} production while others suggest values of 19,000, 25,000 and even as much as 40,000 t d^{-1} (Grande et al., 1994), 43% of the garbage comes from households, 23% from businesses, 10% from markets, 11% from parks and gardens, 1% from hospitals and the rest from a number of different sources.

The organic waste in Mexico City is produced in four ways including: unprocessed (raw) and processed (cooked) waste food, waste of animal origin (mainly excreta, slaughterhouses etc) and crop waste (Losada et al., 2000). In recent years the local government has promoted the separation of organic and non-organic rubbish at household level and has in fact proposed fining those who do not comply with established policies. Some estimates on the levels of use are included in Table 2.

4.1. The Central de Abasto and its Role as a Producer of Organic Waste

The Central de Abasto is the biggest wholesale market in the world; built over an area of 328 hectares, commercial transactions are carried out there 365 days a year. It has 2000 warehouses with a capacity of 155 thousand tons and receives 24,000 tons of natural products a day which represent 40% of national food crops. Of the 800 t d^{-1} of waste produced, mostly organic in origin, 100 tons are used as a source of food-stuff for dairy cows in the market's zone of influence, that is, the eastern part of Mexico City. As well as forage, an important component of the organic waste is the fruit too ripe for human consumption and which is used in the cows' diet (Cortés et al., 2011). The waste products frequently used in the systems of animal production in all spaces in the city are presented in Table 3

The production of residues is markedly seasonal, associated with the harvest times of different products. In spring-summer a number of organic residues are generated, for example: beetroot and turnip leaves and squash (mature fruit).

5. Waste Products Used for Agriculture in Mexico City

The waste products used in the case agriculture include basically excreta from cattle and to a lesser degree pigs, as well as harvest waste (maize stubble) and straw (oats, wheat and barley) from animal bedding in urban stables.
Urban farmers in sub-urban and peri-urban spaces have found a way to use manure suited to their needs as it is a free source of macronutrients (N, K, P) and organic material for the cultivation of vegetables, flowers, ornamental plants, maize, nopal, oats, potatoes, amaranth and other local crops. Functions of equal magnitude that have been adapted by producers include: the contribution of water when fresh manure is used, heat from combustion to reduce the risk of frost damage to sensitive crops (mainly nopal), soil formation in zones with problems of thin soil or in process of erosion, active material to reduce problems of salinity and lastly, soil substitution for the

production of short cycle vegetables (purslane) in soils with problems of salinity such as the Xochimilco and Tlahuacchinampa zone (Cortés et al., 2011). Estimations as to the levels of use of manure in three environments of the metropolitan area are presented in Table 4.

6. Waste products Used for Livestock on Mexico City

6.1.Organic Waste Used for Milk Production

The main organic residues generated in the Central de Abasto are the discarded parts or portions of the principal vegetable and fruit products that are commercialized there, the largest quantity of which comes from vegetables. Carrots are the only waste product in great demand for feeding dairy cattle and possibly pigs. Most residues used for animals are sub-products discarded from products of lesser importance such as sweet-corn, lettuce, cabbage, cauliflower and the leaves of other vegetables, mainly beets, turnips and broccoli. Milk producers prefer to use the residual leaves of sweet-corn, lettuce, cauliflower and, as a last resort, cabbage as feed for dairy cattle.

The use of residues for animal feed has been proposed by a number of researchers in view of their high productive potential, as well as a way of eliminating an important source of contamination in large urban centers (Losada et al., 2000).

An important feature of the flow of these organic waste products from the commercialization centers to the livestock production unit is the fact that it costs nothing except for the cost of collection and transportation. Recently, some alternative uses have been explored by different research groups for the elaboration of composts and organic fertilizers (Monroy, 1981; Cervantes et al., 2007; Saval, 2012).

6.2. Organic Waste used for Meat Production

Pig raising is a practice the population has adopted as a way of mitigating their own poverty. In this sense, animals are seen as a savings bank and the transformation of waste works in benefit of the population's consumption or the generation of economic resources for emergencies. In these types of system the inclusion of non-conventional feed-stuffs is frequent (Góngora, 1983).

Pig production in Mexico is an activity of great importance as it benefits human consumption directly, as is the case of meat, and as a source of secondary products like fat and other products. Although the country has regions that concentrate a large part of the technified pig industry (Schwentesius, 1991), the pig is a species that has been used as back yard livestock, which determines its great potential as a sustainable agricultural model. This situation could be explained from the point of view of the minimal space required to keep them, their elevated capacity to transform waste products, the limited use of contaminating inputs and the recycling of excreta in agriculture, which has encouraged their presence in most regions of the country. There are only a limited number of studies that permit the characterization of backyard production models and the improvement of their production potential as systems capable of providing food for the large population centers sustainably.

These non-conventional feed-stuffs, household waste foods, dry tortilla and bread sweepings from bakeries, are used by up to 80% of the producers. A typical feature of these systems is the sale of animals to cope with urgent economic necessities. The system of commercialization of the farm's pigs include the sale of pigs for fattening and surplus animals sold per kilo live, as well as suckled piglets per unit. Another form of commercialization is sale per unit, the price being agreed between the purchaser and the seller.

7. Conclusion

A common feature amongst the forms of agricultural production in the environs of Mexico City is the divergence existing between what the producers actually do and what the authorities in charge of agricultural development think production should be. The difference between these two components is the determining factor in a dichotomy that often has no solution and which, on the other hand, causes the loss of natural, material and financial resources that could be used for the common good.

An important and positive aspect of the type of models described in this study is the use of organic waste products as inputs. This activity is the result of there being no support policy for producers in Mexico City. Creativity is not necessarily a governmental tool, as the predominant practice is the use of inputs derived from the technified systems, such as balanced feed-stuffs, thoroughbred livestock, feed supplements, selected seeds etc, that make production expensive.

In this sense, more than help, government policies tend towards the creation of new problems for producers that are associated with: the difficulties involved in obtaining the feed-stuffs to improve production including increasing transport costs, serious problems associated with the milk and dairy products market, the acquisition of young animals, waste and finally the encouragement of a system of intermediaries, all of which have been shown to significantly lower the profitability of the production systems. In view of this situation, it is clear that any government proposal at present should start from the fact that the animal and vegetable production systems in the city were created under the specific conditions of the metropolis and thus should be validated as forms of production that correspond to the concept of urban agriculture.

However, an alternative vision of the milk production systems permits us detect a number of advantages afforded by their presence. In the first place, the stables consume an estimated 100 tons a day of organic waste from the Central de Abasto (Grande et al., 1994) which without this use would significantly increase the problems associated with rubbish. The use of sub-products from the food industry, that include dry tortilla and biscuits, dough from maize mills and other products, which in conservative numbers represent a mean value of 30 t d^{-1} with a value in use distributed amongst ruminants, poultry and pigs (Losada et al 2011b). In the absence of these animals, most of the waste they consume would be treated as rubbish as the local market where it is sold would be limited. Another positive factor of the dairy stables is the generation of waste products used in the nopal fields in the southern zone of the city. Although a remedial alternative could be established using manure from technified production units, it could be suggested that that the impact would be direct as transportation distances would increase and it would require a re-education process amongst producers governed by the concept of supply and demand, who, when faced with high demand for manure from nopal producers, would put a sale price on manure which at present does not occur. This practice would undeniably have repercussions in the form of a cost increase in nopal production or, discourage the use of manure which in turn would encourage the use of non-organic fertilizers that cause pollution.

Despite the great advantages mentioned for the nopal-vegetable, vegetable and flower systems as well as for other crops in the area, an analysis oriented towards sustainability has permitted the proposal of a number of interesting hypothesis that bring to light the stability of the system from three points of view. The first of these is related to the intensive use of livestock manure which, according to the values reported for use per hectare (600t d^{-1}), constitutes a theoretical contribution of approximately 2000 kg of N, 124 kg of P and 308 kg of K (Grande et al., 1995). Given this situation, it is clear to most researchers that there is an excessive use of N as the major element associated with plant productivity, the surplus quantities of which could contaminate surface water courses and the deep water tables. This possibility increases as in the most of the cases reported, the use of excreta is complemented by the addition of N,P,K from non-organic sources with theoretically calculated values of: 212 kg ha^{-1} N, as well as an extra source of these components from organic material from the plant itself which is dug into the soil during the pruning season in order to activate the growth of new leaves.

A collateral problem present in the system of nopal production, for example, is that related to model of monoculture as a predominant form and promoted by the producers of the area, which is a threat to the biological diversity expected that would increase the system's productivity. The reasons for this decision by producers are to be found in the difficulties involved in establishing associated crops in the central paths due to the intensity of the work in the plantation as well as the competition for nutrients, which in most cases encourages the control of the growth of other plants most of the year except in spring when prices are low.

With the new proposal for sustainability and the later forums (FMAM 2000), the need to make cities sustainable is one of the greatest challenges for local authorities, in particular with reference to the change of forms of consumption and waste generation. While the necessity to modify the way of life in Mexico City motivates government plans, conferences and research which still have to generate a proposal, the city farmer (now urban) and the inhabitants of the vulnerable sectors have not been strangers to change, as their great cultural experience in agriculture is the broadest sense of the word, in addition to the inherent needs of their crops and animals, have meant that they have found in organic rubbish, a major resource of local inputs to be incorporated into their production processes.

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9. Tables

Table 1: Physical-Urban Characteristics of the Spaces in which urban Agriculture is Carried out in Mexico City

	Urban	Sub-urban	Peri-urban
Buildings/km^2	0.829	0.125	0.002
Streets/km^2	0.156	0.015	0.002
Open spaces/km^2	0.010	0.850	0.880
Canals/km^2	-------	0.005	--------
Woodland/km^2	-------	-------	0.115

Table 2. Estimations for the use of Solid Biological waste in the Metropolitian area of Mexico City

Type of waste	t d^{-1}	Estimated use
Vegetables and fruit from the Central de Abasto	100	Forrage for 2500 cows (38,000 L milk d^{-1})
Domestic and restaurant waste	190	47,000 pigs
Food industry and domestic waste	200	500,000 birds
Vegetable waste from local markets	2	15,000 rabbits

Table 3. Waste products used for different animal species

Waste products	Species for which they are used
Vetegetables and fruit from markets	Bovines, pigs, poultry and rabbits
Dry tortilla	Bovines, pigs, poultry and rabbits
Dry tortilla dough	Bovines and pigs
Dry bread	Bovines, pigs, poultry and rabbits
Wastebisuit	Bovines
Bakery sweepings (bread which has fallen on the floor)	Pigs
Butchers' shop sweepings (leftover meat and bone)	Pigs
Juice stallwaste	Pigs
Kitchen and restaurant waste	Poultry and pigs
Householdwaste (food)	Poultry and pigs
Chickenentrails	Pigs
Grass from pavements and/or gardens	Bovines, equines and sheep

Table 4. Levels Calculated For Dairy Cattle Excreta use in 3 Agricultural Models in the Metropolitan Environs of Mexico City

Productionmodel	Quantity of excreta[1]	Productobtained
Chianampa(1650 ha)	360,000 tons	Vegetables, flowers and ornamental plants
Terrace(2400 ha)	1000,000 tons	Nopal, maize
Teotihuacán(10,000 ha)	560,000 tons	Green tuna and xoconoztle