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Recycling of solid wastes in Mexico City in livestock and agricultural production systems as a sustainable alternative

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Abstract. The use of solid organic wastes (manure and fruit and vegetable refusals) as a way to recycle rubbish from peri-urban areas for the production of crops for local consumption, has been designated by some researchers as an alternate method to partially reduce city waste disposal problems as well as to generate employment and promote the consumption of local products. This model production has also been suggested as a closed system ideally suited for urban environments in order to reduce the use of external inputs and encourage waste recycling policies for resource usage. A system that uses a significant amount of solid waste in the form of fruits and vegetables and the local food industry to feed dairy cows has been implemented in the East of Mexico City. The stable refusal consisting of manure and straw are sent in a fresh way to agricultural areas of the South-East of the city and used as an important external input support for the production of nopal-verdura which constitutes an important food in the diet of the inhabitants of Mexico City. The main goal of this paper is to expose and analyze current and future advantages and problems in both systems as sustainable alternatives for waste management.

Keywords. Urban agriculture, nopal, vegetable, Opuntia, manure, dairy cows.

1 Introduction

The Valley of Mexico is a closed space with an extension of approximately 9600 km^2, in the center of which Mexico City and its metropolitan area are located. The zone is included in the geographical space of the cultural area known as Mesoamerica, which, along with the central Andes zone forms nuclear America, that is to say, the region where the great Pre-Hispanic urban civilizations flourished. Agriculture was an activity of great importance carried out in the Valley of Mexico and constituted the economic foundation of the societies that established themselves by means of their different forms of production and the repertoire of domesticated plants adapted to this environment. The early colonial period, considered by some authors as a time when the western model was imported, 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 mining. In the centuries that followed, the importance of the city's agriculture as an economic activity gradually diminished. This was particularly the case from the early the 20th century onwards due to the industrial revolution and later, in the early 1950's when the country took up the offer of development and modernization. The agriculture that survived was atomized as the agricultural zones were displaced by buildings and the loss of its labor force that went in search of permanent, better paid jobs. Despite this, the strong cultural ties of the local and migrant populations to Pre-Hispanic Mexico, created the conditions for the birth of a new form of urban agriculture that assimilated the city's waste products in order to convert them into its own production inputs. This study analyzes agriculture and technology in the face of the phenomenon of urbanization, in order to understand the structural bases of urban agriculture and its perspectives in the context of globalization.

2 Food production for Mexico City

The production of food by the country's agricultural sector to provision Mexico City is carried out using two basic models. That is, a vertical one derived from the green revolution (Taceña, 1973, Zúñiga, 1980) which uses great quantities of external inputs to sustain high productivity levels in contrast to the second horizontal model that includes a large number of landholders who produce in traditional ways using a limited amount of inputs (Rojas, 1990). Although the vertical agricultural model has permitted the production of large volumes of food capable of satisfying the needs of the large urban centers, there is clear evidence in the literature of an adverse trend towards mono-cropping in the case of this type of technology (SPP, 1983). There is also serious environmental deterioration resulting from indiscriminate use of external inputs that even manifests itself in problems of public health as the presence of agrochemicals are frequently reported in foods consumed by human beings (Calvin, 1973). Given this situation at present most developed countries are orienting themselves towards the search for production models that recue the model of biological diversity of species and a minimum use of external inputs (BID, 1990). This means that traditional systems of production potentially provide indicators of the rational use of renewable natural resources.

3 Agricultural development of the Federal District and its metropolitan zone

The premise of finding alternative systems with high production and low levels of contamination is an indispensable prerequisite for the implementation of rural development strategies in the Federal District's agricultural sector. At present, there are seven Delegations that are considered agricultural: Tláhuac, Xochimilco, Milpa Alta, Tlalpan, Magdalena Contreras, Alvaro Obregón and Cuajimalpa, which together have a total surface of 32,000 hectares dedicated to agriculture, 36,000 hect. to forestry, 14,000 hect. to pasture and approximately 1,000 hect. that are flooded and which constitute as important biotic resource for the metropolis (Sánchez, 1982). Despite this situation, the Federal District's agricultural sector faces serious problems that threaten the quality of life of its inhabitants. Amongst these we should point out: (1) the excessive urban sprawl that threatens to get out of control altogether due to the reform of Article 27 of the Constitution (Rodríguez, 1990) legalizing the sale of ejidal lands as thus giving them greater exchange value than usage value; (2) abandoning of primary and secondary activities (agriculture and/or livestock) caused by the migration of farmers to the city in search of sources of permanent work and the repercussions of which are reflected in low productivity in agricultural systems as well as an increase in levels of soil erosion and the presence of dust storms due to the loss of plant cover and (3) a decline in the process of aquifer recharging and the persistent contamination of water, air and soil which increases the seriousness of environmental deterioration due to the degradation of the natural habitats of wild fauna and flora (López, 1988, Canabal, 1991). Under these conditions, there is an obvious need to find new, environmentally sustainable production models that permit high production yields so that a revalued usage value of the land inhibits urban growth, prevents migration of farmers and provides real benefits for the local population.

4 Alternative agricultural and livestock production systems

An analysis of traditional production systems implemented in the agricultural and livestock region of the Federal District using the fundamental criteria of historical antecedents, rational use of resources and high productive potential has permitted our research group to detect the zones of greatest importance located in the east and south of Mexico City. In the first zone studied, most research work has focused on the production systems of the Iztapalapa district where the presence of three predominant species has been reported: dairy cattle, pigs and poultry. (Losada *et al*, 1992, Losada *et al*, 1994 and Cortés *et al*, 1994). In the southern zone, that includes the districts of Xochimilco, Milpa Alta and Tlahuac, the production systems maintain the conventional form of the rural sector in the rest of the country, with agriculture as a dominant activity and livestock and forestry systems as secondary sectors closely integrated with agricultural activity.

The production systems we have studied have shown a close interrelation of the models in both zones that function on the basis of having established a binomial frequently reported in the area. This consists of using the waste products of one system as a source of energy and macronutrients (N, P, K) for the other system which establishes it as the ideal condition for the construction of a sustainable alternative. The models include the dairy production system in Iztapalapa that gives intensive use to the potentially contaminating organic waste from the Central de Abasto, the central wholesale market (vegetable and fruit waste), from the local population (tortilla, bread and kitchen waste) and the food industry (cookies, dough, bread). The waste products of the dairy system (livestock excreta and bedding) are sent to the terraced zone in the south of the city. The second system is the production of nopal in Milpa Alta that receives the excreta from the dairy livestock and uses it as a source of organic matter, macronutrients (N, K, P), water and the heat from combustion required for growing nopal-vegetable. This is a cactus (Opuntia ficus indica) adapted to the zone with specific requirements of water, growth habits on eroded, low quality soils and with natural restrictions for its mechanization, the products of which (leaves or cladioles) are mainly consumed in Mexico City, the neighboring states and exported to the USA and Japan. A common feature of both models is their close interrelation based on the production and use of excreta as the linking agent which has permitted producers in both systems to maintain their importance despite the serious problems that exist in the agricultural environment (Canabal, 1991).

4.1 Milk production in Iztapalapa

4.1.1 The Iztapalapa delegation

Iztapalapa, (a Nahuatl word meaning "the water on the stone slabs") situated in the east of the city, is one of the Federal District's 16 political entities. Its climate is classified as: C(w2)(w) and BS1k which corresponds to sub-humid and semidry cool respectively, with a mean annual temperature in the range of 15.3 and 16.6 degrees C. The mean annual rainfall is 530-617 mm. with a rainy season between May and October (García, 1981) The total area of the delegation is 117 square km of which 75% are used for urban purposes. It has 17,181,105 sq. meters of roads and a total number of 182 traffic lights. The population is estimated to be 2,189,592 inhabitants (INEGI, 1994), the equivalent of

Table 1. The mean size of the herds in Iztapalapa

Cows in production	21
Dry cows	3
Calves	2
Total	27

Table 2. Frequency of utilization of feeds for dairy cattle at Iztapalapa

	Proportion of producers using the feeds (%)
Lucerne hay	74
Wheat bran	52
Maize stover	52
Fruit/vegetable rejects	48
Commercial concentrates	43
Introduced grasses	30
Ground maize	33
Oat grain	11
Coconut oilmeal cake	9
Bread scraps	9
Sugarcane bagasse	7
Tortilla	7
Fermented maize dough	7
Distillery bagasse	4
Oat straw	4
Groundnut hulls	2
Soya bean meal	2

18,714 inhabitants per sq. km. The zone has shown a population increase over the past fifty years coming from two main sources: locals and migrants that live in 15 villages and 182 urban neighborhoods (colonias). Access to services in the zone includes: drinking water (75%), drains and sewage (70%), electricity (90%), street lighting (70%) and paved surfaces (50%) (Losada *et al*, 1992). Measured in terms of average income, the population has been classified as extremely poor (Sánchez, 1982), with a high participation of the elderly, women and children in the provision of the family income. The main economic activities are: manufacturing industry, commerce and services (Montaño and Rendón, 1992). In the center of the delegation is the city's main wholesale market (Central de Abastos) with an estimated area of 328 hects. and where commercial transactions are carried out 365 days a year. It has 2,000 warehouses with a capacity of 155 thousand tons and receives 24,000 tons of natural products daily, which constitutes 40% of the national food harvest. Of the 800 tons/day waste production, mostly organic in origin, 100 tons are used as a source of forage to feed dairy cattle in this enormous market's area of influence, that is, the east side of Mexico City. An alternative use for fruits that are no longer suitable for human consumption is in the stables where they provide appropriate cattle feed. At present, Iztapalapa is considered to be a delegation with one of the highest crime rates including vehicle theft, robbing passers-by, and burgling businesses and dwellings.

4.1.2 Milk production in Iztapalapa

According to data reported in our sources, the presence of domestic animals includes 12,000 head of dairy cattle, 20,000 pigs and 300,000 poultry (SIC, 2000).

Milk production in Iztapalapa goes back to colonial times and the presence of livestock haciendas or estates which supplied the inhabitants of Mexico City with products (Montaño, 1984). Over time, the forms of milk production maintained their structural function without undergoing radical transformation due to changes in land tenure until 1954 when a presidential decree designated the delegation as an urban area (Diario Oficial, 1954). This situation set in motion urban growth around the edges of the city, modifying the system of milk production from the conventional ranch type to its present stable form.

According to our research, Losada *et al*, 1992, Cortés, 1993, Vieyra *et al*, 1994 and Cortés *et al*, 1994), the average stable in Iztapalapa is physically located in the urban zones in a building that shares the space of the family dwelling. The stables in Iztapalapa are concentrated in the ancient villages today transformed into residential areas, colonias and/or barrios, one of which is on the edge of the Central de Abastos, and all of them combine the presence of animals with a dwelling on the same plot. As far as the delegation authorities (local government) are concerned, the property is registered as a dwelling and so pays for all services: local property rates, electricity, water, and individual ones (telephone) while those corresponding to street cleaning, sewage, rubbish collection are included in other taxes (income tax). Local rates are paid once a year, electricity is paid for once a month, and water quarterly. Individual services are for paid once a month or yearly in tax declarations.

The average herd size in the delegation (see table 1) is 27 animals, of the commercial Holstein breed. Most of them are cows in production and the rest are calves or bulls

Table 3. Main portion of vegetable and fruit rejects used to feed cows in the stables of Iztapalapa

Food item	Portion		
	Leaf	Fruit	Flower
Broccoli	*		*
Cauliflower	*		
Lettuce	*		
Carrot		*	
Corn	*	*	
Pumpkin		*	
Cabbage		*	
Radish	*		
Turnip	*		
Sugar beet	*		

The feed system is made up of a wide range of feedstuffs (see table 2) from the conventional system of milk production in the Mexico (alfalfa/lucerne, maize stover y commercial concentrates, Gallo y Peralta 1976) as well as approximately 15 components derived from the organic residues in the Central de Abastos (see table 3) and the food industry such as sweet corn, cabbage, cauliflower, lettuce, carrots, bread, maize dough, tortilla and others.

The milking method is manual, and the mean milk production is 15 liters/animal/day and a lactation period of 230 days is reported. The method for crossing animals is direct mounting and only a small percentage of producers use artificial insemination while the presence of disease is limited to pneumonia, mastitis, and hoof rot.

Animals are replaced by raising calves in the case of only a minority of producers, as most of them acquire adult animals in the surrounding technified dairy producing zones. Animal selection criteria (table 4) are body conformation and milk production from the mother, while the criteria for disposing of them are the age of the cows, low production, financial emergencies and in a few cases, chronic illnesses.

The system for commercializing milk includes the predominant form of direct sale to the consumer at the stable as well as to a lesser extent, home delivery, while milk products: cream, cheese and desserts are sold at the stables and at local markets. In all the stables, the animal excreta is collected periodically along with the bedding and is donated fresh to be sent to the agricultural delegations to be used as a source of organic matter and fertilizer for different products the most important of which is the nopal.

Table 4. Criteria for selecting cows in the stables of Iztapalapa

Criteria	Percentage
Body conformation	39
Body conformation/milk production	36
Previous production	13
Breed	4
Other	8

4.2 Nopal production in Milpa Alta

4.2.1 The Milpa Alta delegation

The delegation of Milpa Alta forms part of the mountainous structure of the south of Mexico City at an altude of 2420 m.a.s.l. with a range of between 2470 and 2750 m.a.s.l. and topography recognized having a gradient of 20 to 60%. The soil in this area is volcanic in origin with the presence of rhyolites, andesites, basalts, conglomerates, volcanic foams and ash. Although the zone presents some soils as deep as 50 cm. most are in the range of 25 to 50 com (INEGI). The predominant color of the soil is brown and the texture is classified as medium clay while most of the soils in the higher zone are sandy. The structure is granulated or angular block with good drainage. The zone lacks natural rivers although there are some seasonal streams. The climate of this zone has been classified as C(WO)(W) which means it is temperate and sub-humid with a low degree of humidity (García, 1981). The average annual temperature is 16 degrees C. and the average rainfall is 600 to 800 mm per year, distributed over the summer from May to October Frosts occur in the high parts during the months of December and January. The natural vegetation in the forests includes different species of pine (P. Teocote, P. Leiphylla, P. Montezumae, P. Hartwegii and P. Ayacahuite), oaks (Quercus spp), savin (Juniperus spp), alder (Alnus spp), capulín (Prunus capuli) and amongst others. The ground flora is made up of perennial and annual grasses (Graminae) of the genus: Muhlenbergia, Festuca, Sporobolus, Heteropogon, Agrostis and others. The The presence of xerophytic shrubs includes species such as: Schinus molle, mimosa biuncifera, Opuntia spp, agave spp and Eysenhardtia ploystachya (Alonso, 1995).

The nopal (Opuntia Ficus indica) in the zone of Milpa Alta is original to the area and was domesticated by the ancient inhabitants and selected for the production of its leaves (cladioles) for human consumption (Rojas, 1990). Today, it can be considered the zone's most important perennial crop, with a cultivated surface of approximately 6,000 hects. and

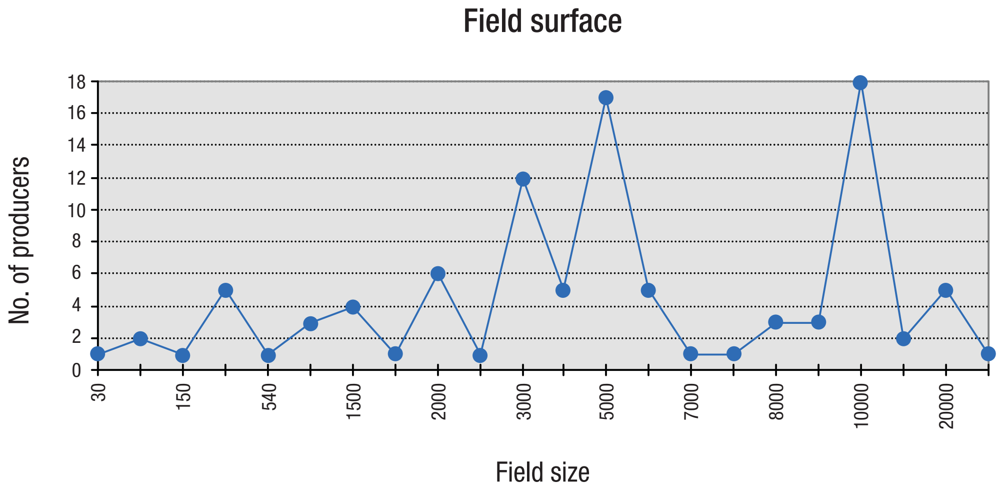

Figure 1. Relation between the surface of nopal plantations and the number of producers in the nopal producing zone studied

production of more than 200,000 tons of leaves. 75% of these are consumed in Mexico City and the rest in neighboring states (Puebla, Hidalgo, México, Querétaro etc.) while a small surplus is exported mainly to the USA and Japán.

According to our research, (Rivers *et al*, 1994 and Losada *et al*, 1995), the cultivation of nopal is localized mainly in the terraced zone on yellowish and/or brown soils with both sandy and clay characteristics. In general terms, it can be said that there is no definite season for planting nopal as the choice of times is subject to a series of factors that have nothing to do with the plant. The predominant system in most of the zone corresponds to the traditional one, with a mean distance between of 20cm and a path between furrows of 1.2 m. The number of plants per square meter is in the range of 8 to 10 leaves. Most nopal plantations are sown on fields of 0.3 to 0.6 hects., in contrast to those of about a hectare of which there are few in the zone as is shown in Figure 1.

In most cases, cultivation includes weeding, pruning, fertilization, treatment of diseases and harvesting which is done manually using regional tools (Rivera *et al*, 1993). From the production point of view, the nopal plantation has three marked periods that govern market prices: winter, in the months of December and January with low production and high prices; spring, with high plantation productivity and low prices; and summer, with profitable production and price levels. Mean values calculated for the production of nopal leaves are in the order of 750, 1750 and 5,500 cladioles corresponding to the winter, summer and spring seasons respectively.

In all the nopal plantations, the use of bovine excreta as a source of organic matter and fertilizer is intensive as is shown in table 5.

As can be seen, the mean value reported is 600 tons of fresh excreta per hect. per year, which directly supports a weekly production of leaves involving weeding and other activities, throughout the year (52 crops). Some collateral functions of the excreta have been pointed out by producers such as its being a source of water and heat required during periods of drought and cold respectively (Grande *et al*, 1995). The use of inorganic fertilizers is restricted amongst producers with products such as N17, Ammonium Sulfate and others. Although there is persistent labor on the part of producers, on some occasions agrochemicals are used to combat weeds, insects and fungi that affect the plants directly. The mean age of the nopal plant is in the range of 5 to 20 years, depending on the productivity of the crop and other factors.

Table 5. Organic fertilizers and amounts used according to the traditional areas (1 yoke = 0.3 ha)

Inorganic	kg Manure	Tones
Small yoke	750	>200
Medium yoke	850	>300
Large yoke	1000	>400

The nopal market included the direct sale of leaves at local markets as well as sending them to the big market in Mexico City (Central de Abastos) where they will be retailed in the city's markets, supermarkets and other sales points. In all cases, there is definite influence of the production period that determines the price of the product offered and which effects demand.

4.2.2 Sustainability of the nopal-legume cuñtivation

The evaluation of sustainability of five indicators in the cultivation of nopal is included in table 6. As would be expected, the high values correspond to social indicators, as the nopal constitutes one of the few crops that have kept the periurban population of Milpa Alta working in their fields, thus

Table 6. Qualifiaction of sustainability using indicators representative of the social, economic and environmental indicators in the nopal plantations of Milpa Alta

Social	Qualification	Economic	Qualification	Environmental	Qualification
Homogeneity	16	Employment	16	Production system	20
Offer of employment	18	Annual capital flow	18	Tools	20
Field surface	17	Seasonal capital flow	10	Fertilization	12
Knowledge of the environment	20	Capital flow per field	14	Pest control	2
Organization	18	Comercialization	16	Biological Diversity	10
Total	89	Total	74	Total	64

inhibiting urban sprawl caused by abandoning of agriculture as has happened in other zones. The intense human activity demanded for the cultivation of nopal all year round, has provided work for external temporary workers, which strengthens social ties of the local community. With respect to field size, the wide range of spaces planted with nopal establishes an equitable distribution of the means of production in benefit of broad sectors of the population which, along with detailed knowledge of the crop and therefore of nature, functions as an element that anchors the activity of local farmers. Lastly, community cohesion is reflected in different forms of organization for the collective solution of problems.

Due to the specific characteristics of the nopal-vegetable plant that has been selected for year round production which guarantees at least one crop/week, the production system can be compared to the production of milk, as it provides the producer with money every week. This same characteristic makes employment available as a means of acquiring resources although payment is regulated by public policies that introduce an undesired variable. Although the gross annual capital flows are high, the high degree of dispersion that exists due to field size means that small field owners do not satisfy the needs of their families thus requiring other sources of employment to supplement them. Similarly, the great variability introduced by the effect of the season in the distribution of capital flow tends to accentuate the problems of income within this sector of producers. Lastly, despite the fact that producers in the nopal communities tend to organize themselves in order to solve problems, there are still a number of problems associated with the commercialization of the product. One case is that of intermediaries who reduce the producer's profits.

The indicators associated with the preservation of the environment tend to towards polarization. While the prevailing production system is traditional, it is feasible to make rational use of the soil and cultivation technology (tools used for cultivation) based on the use of local manual tools. On the other hand, inorganic fertilizers and pesticides that contaminate the environment. The role of organic fertilizer however, represents an element of ambiguity as it supplies MO and macronutrients (N.P.K) of organic origin as well as collateral functions: water and heat from combustion, considered as ways of replacing inorganic compounds. However, the high degree of dependence of the crop on the use of excreta could become a limiting factor in the future when faced with the possibility of its use being restricted by a policy aimed a preserving the environment. Finally, there is a clear trend towards not producing nopal in association with other crops, which along with the reduced number of varieties identified by producers (white and yellow tunas), tends towards a loss of some characteristics of regional adaptation that might increase dependence on the use of external inputs.

5 Nutrient flows in the integrated production system

The close association that exists between the system of milk production within the Valle de Mexico basin and the prevailing agricultural systems in the sub and peri-urban spaces (the most representative example of which is nopal), constitutes without a doubt a production model that is adjusted to the conditions of sustainability desired for large urban centers. The balance of macronutrients (N, P, K) obtained through the use of the waste products form the Central de Abastos and the stables and lastly, the massive contribution they make to the nopal fields (figure 2) confirms the presence of a closed cycle in the use of these components.

The efficiency with which energy and macronutrients are used in the field reported by us in previous studies (Losada *et al*, 1996), is not so good in terms of the biomass produced, although as we have pointed out, the most important contribution is the recycling of energy of biological origin that constitutes a renewable nature resource. This contrasts with the productions systems of conventional industrialized crops (such as vegetables) that are highly dependent on the use of non-renewable fossil resources. A second contribution,

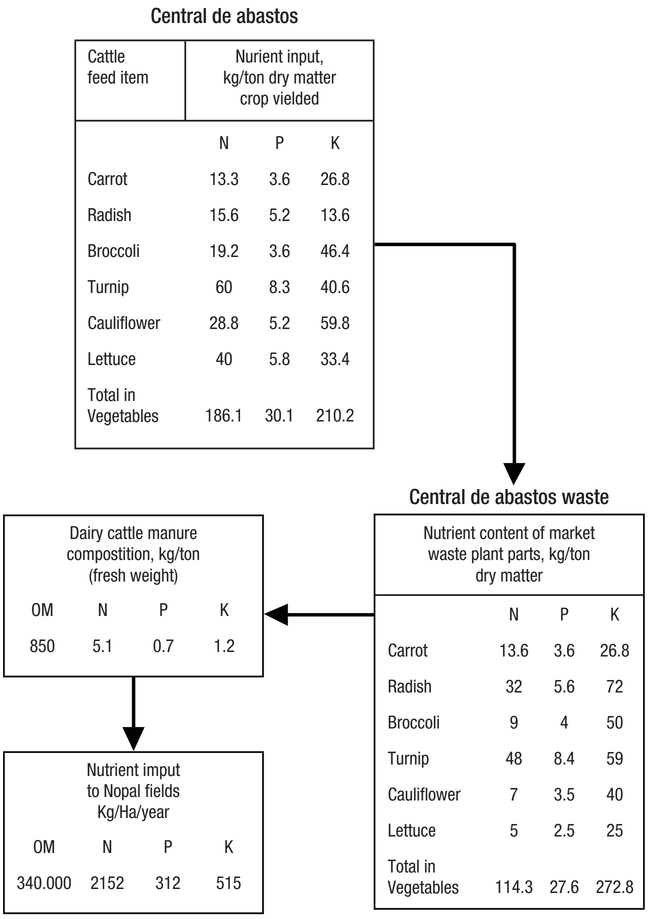

Figure 2. Recycling of Macronutrients (N, P, K) and the organic matter (OM) by dairy stables using market wastages in México City

perhaps of more importance still in relation to the use of macronutrients, refers to medium term soil formation, which will directly contribute to better living conditions for the inhabitants of Mexico City.

6 Analysis of the problems facing the milk and nopal production systems in the environs of Mexico City

A common characteristic that traditional forms of agricultural production have faced in the environs of Mexico City is great divergence existing between what producers do and what the authorities in charge of agricultural livestock development think production should be. The difference between each component has resulted in a dichotomy that frequently has no solution and in fact, causes a loss of natural, material and financial resources that could be used for the common good.

The production system in Iztapalapa faces the problem of being considered a semi-clandestine activity, as the area has supposedly been defined as an urban delegation. However, despite existing legal restrictions, statistical data indicates the existence of an estimated 12,000 diary cows distributed amongst the stables giving it a semi-overt nature.

During the course of our research, interviews with local government officials brought to light a series of problems associated with the stables that a cause for complaint by neighbors. Amongst these are the presence of flies and rats associated with the handling of excreta and feedstuffs, as well as the blocking of urban drains, the excessive use of water and the lack of hygiene in the management of the cows and the milk when it is sold to the public. While these complaints are true, the evidence shows that there are a series of factors that propitiate or inhibit their presence such as the time the stable has existed in a particular urban space as well as the pressure exerted by construction companies in search of land suitable for the building of apartment blocks (Losada *et al*, 1995).

A possibility presented on a number occasions by the authorities of Mexico City aimed at solving the problem of the stables with their neighbors has been to take them out of their urban context and relocate them on the outskirts of the metropolis. Examples of such proposals are the creation of the dairy producing regions of Tizayuca (which brought together the dairy stables of Santa Ursula Coapa and Xochimilco) and the recently created dairy region of Xochimilco that grouped the producers of the chinampa zone of Xochimilco (Losada *et al*, 1994). Despite the investments made by the Mexico City's government in the construction of stables as well as high levels of support for production, available evidence up until now is negative as the results are disheartening as they include the sale of animals and in the last instance the real loss of the systems. An analysis of the problems reported, has forcefully pointed out the creation of new problems for producers associated with the difficulties in obtaining feedstuffs for production. The increase in the costs of transporting them, serious problems associated with the marketing of milk and milk products as well as those related to young animals or useless animals and the encouragement of intermediaries, all of which have been shown to lower the profitability of the production system. Given this situation, it is clear that any government proposal today should be based on the fact that that the dairy production systems in the city were created under the specific conditions in the metropolis and that they should therefore be validated as forms of production that correspond to the concept of urban agriculture.

An alternative view of the dairy production systems in Iztapalapa however would let us detect a series of advantages of the presence of stables in the area. In the first place the stables consume an estimated 100 tons of sold waste from the Central de Abastos a day.(Grande *et al*, 1994) and in their absence the problems associated with garbage would increase significantly. A large volume of by-products from the food industry are also used and include tortillas, stale bread and cookies, dough from maize mills and other products, which even conservative estimates calculate at 30 tons/day. Although these groups of foods could be of value for monogastric species (poultry and pigs, Losada *et al*, 1994 and Cortés *et al*, 1994)), it is clear that in the absence of the stables, most of them would go to waste as there would only be a limited local market for them. On the other hand, it is obvious that the existence of the stables in the zone has increased the number of jobs available, both for those who work directly with the animals and also indirectly, for those associated with the food, health, construction and others that support dairy activity. Lastly, it is evident that the greatest impact caused by the abolition of the stables in and around Iztapalapa would be directly associated with the producers of nopal and other crops in the south of Mexico City who use excreta as a major source of organic matter and nutrients to support the high crop yields. An alternative remedy could be established by the use of excreta in the technified dairy regions. However it could be suggested that the impact would be as the transport distance would increase and require a process of re-education for dairy producers governed by the concept of supply and demand and who, in the face of the high levels of demand for excreta amongst nopal producers, would try to fix a sale price for manure (at present absent). This would undeniably result in an increase of nopal production costs and if not that, discourage use of excreta and thus encourage the use of inorganic fertilizers that cause contamination.

Problems at present associated with the production of nopal differ considerably from those in faced in milk production in urban systems. Although the agricultural development programs in the area are oriented towards the indiscriminate use of external inputs, the topography of the zone with gradients between 20 and 60%, the extensive presence of Pre-Hispanic terraces and small-holding restrict the use of mechanized cultivation (Losada *et al*, 1995), the latter being associated with the extensive use of external inputs. In consequence of this restricted production framework, the presence of the nopal as a native product of the zone found an ideal niche to establish itself in intensive commercial conditions, undeniably encouraged by the high levels of demand for this product in most social strata of Mexico City. This undoubtedly constitutes strong cultural pressure that supports the propagation of the plant. The result of this cultural pressure and of a suitable environment has meant that Milpa Alta has shifted away from the reality of the rural zone of the metropolis, as most of the socio-economic problems affecting the rural delegations were halted in this area by the presence of the nopal. This is evident in the revaluation of the usage value of the land that restricted the change towards urban forms as well as the inhibiting the phenomenon of migration amongst local farmers and increasing the offer of jobs to the workforce from other neighboring states.

Despite the great advantages of the nopal system already mentioned, the application of an analysis oriented has permitted us to propose a number of interesting hypothesis that would put the stability of the system at risk from three different points of view. The first of these is related to the intensive use of cattle excreta, which according to the values reported for its use per hectare (600 tons/year) theoretically provides 2000 kg of N, 124 kg of P and 308 kg of K (Grande *et al*, 1995). According to this data it is clear for most researchers that there is excessive use of N as a key element associated with the productivity of the plant, and a surplus of which could function as a pollutant of surface streams and deep aquifers. This possibility increases as in most of the cases reported the use of excreta is complemented by the supply of extra N, P, and K derived from inorganic sources (N17) with theoretical values calculated as: 212 kg/hect. of N, P and K respectively and as an extra source of these components from organic matter from the plant that is incorporated into soil during the pruning seasons and used to activate the growth of new leaves. The second set of problems detected is associated with the use of agrochemicals used by producers to combat insects and diseases in the plant, the residues of which in the leaves have been the cause of temporary suspensions of nopal exports. A clear example of this situation occurred due to the restrictions imposed for export to Japan, which can be considered responsible for reductions in the sale price of the product. It also possibly had the parallel effect of stopping the expansion of this crop into neighboring lands used at this time for less productive crops and which in turn propitiated the urbanization of agricultural land.

A collateral problem present in the nopal production system is that related to the model of mono-cropping as the prevailing form and promoted by the producers in the area. This is a threat to the biological diversity that it hoped will increase the system's productivity. Although there are some indications of crop diversity in nopal plantations, as is the case of the production of ornamental plants (mainly geraniums) grown for sale by women, as an alternative way to earn income, the prevailing trend to date is mono-cropping. The reasons behind this decision is based on the difficulty producers have to establish associated crops in the central lanes due to the intensiveness of the work in the plantation along with the competition for nutrients. This means that in most cases, except in the spring when prices are low, the nopal plantations are kept weeded all the time. Thus, it is clear that while the nopal is the one and only crop, it is extremely prone to attacks from pests and insects.

7 Further research required

An analysis of the problems that affect agricultural development in the Federal District establish the urgent need for researchers and local authorities to find new forms of production based on the principle of environmental, social and economic sustainability that will generate collective well-being for its inhabitants. There is no doubt that the construction of a model of sustainability is not easy to do due to the lack of information in the different fields required for a new proposal. However, it is also clear that the definition of a model should give priority to prevailing forms that permit us on the one hand, to reduce problems of contamination, and on the other, to achieve high yields that encourage agricultural activities as happens in the case of milk production in Iztapalapa and nopal in the south of the city.

Our research experience to date in the study of both production systems has established the need to involve the agents responsible for production, consumption and research in the search for common solutions to different problems. This being the case, we have considered it appropriate to generate work strategies that facilitate specific research into each system within the model of university extension that will permit working on a day-to-day basis in the communities studied taking into account the forms of production as well as their environmental, socio-economic and cultural environments. In this sense, the premise of the study is that the proposal include the Environmental Impact Evaluation methodology in relation tp the direct and indirect socio-economic factors that intervene in the production of both systems.

With respect to research on the system of milk production in Izatapalapa, the analysis would include following the productivity of a representative sample of stables over a period of a least 12 months, which would permit us to understand the seasonal variation in the use of organic waste and how this is reflected in milk production. The same study would make it possible to learn about the changes occurring in other variables of interest for the study, including the number of animals in production, births, length of the lactation period, arrival and departure of animals, real excreta production levels and its management as well as real costs of production.

In parallel to this, the study should involve research into the demand for milk by consumers and their preferences as they directly form part of the functional marketing structure associated with the practice and the socio-economic support of the stable in the delegation. The study should also widen its scope to consider the social environment of the area where the stable is geographically located and where the milk and milk products are not necessarily consumed. This would provide us with knowledge of the degree of acceptance the unit has in its social environment, and also to establish the real problems that affect the community: flies, rats, odors, blocked drains, water consumption and handling of the milk. We could also study the possibility of installing containers for known excreta in order to eliminate the problems of odors, flies and rats, increase efficiency in water use, recycle nutrients (N and P) to reduce production costs and to improve the proportions of C/N in the residues in order to give them optimal use in the agricultural processes in the zone where they are received. Lastly, a study of this nature should include four fundamental aspects: (1) the estimation of the production and consumption of organic agro-industrial waste with characteristics of real or potential refuse; (2) the generation of employment directly or indirectly associated with the stable; (3) the estimated cost of moving the stables to the dairy production areas on the outskirts of the city. (4) Finally, we should to the role of the local authorities in the delegation in their normative and administrative capacity along with that of the University as a center of knowledge obtained through research along with links between the different actors that intervene in production.

The methodology to be applied in the study of the nopal system in Milpa Alta within the sustainability model should be similar to that established for Iztapalapa. That is to say, the research should follow a representative sample of nopal producers over a period of at least 12 months to obtain information on the productivity of the system, as well as cultivation tasks and use of bovine excreta in order to understand the seasonal variations that exist in production. Similarly, it would be necessary to analize the social environment of the plantation to learn about the contribution made by the local and external labor force as well as the contribution nopal production makes to the total family income. On the other hand, it would be necessary to carry out the pertinent studies associated with (1) the biodiversity of both flora and fauna in the production of nopal, (2) the physical-chemical characteristics of the soil and superficial and underground water sources which would permit the detection of possible contaminants such as nitrogen and toxic agro-chemicals, as well as (3) to evaluate the productivity of the crop using solid waste from excreta fermentation tanks as a resource that reduce the possible contaminating effects of excreta and improve the C/N relation required to achieve better use of nitrogen in nopal production.

This study should also include a calculation of nopal plantation production costs compared to those of the zone's crop "par excellence", maize, which would permit us to understand the economic feasibility of year-round soil use for nopal production in relation to the seasonal and temporary production of the other important crop in this area. Similarly, it would be necessary to monitor on a weekly basis the local market prices as well as the cultural factors associated with nopal consumption that interact in how prices are fixed. Finally, a study should be done in order to quantify the impact that an increase in the present day value and transport costs of bovine excreta would have on nopal productivity as well as the risks involved in substituting it with the intensive use of inorganic fertilizers which could be associated with potential changes in the presence of stables in the urban environment of Mexico City. Similarly to the case of dairy production in Iztapalapa, it would be necessary to include a study of the role of the local authorities in the delegation as those responsible for agricultural development policies as well as the University, as it is responsible for research and the generation of knowledge.

Although some researchers have criticized the interest in city agriculture due to its limited contribution to national food production or to the regional economy, its importance is justified by its incorporation into an improved way of life for unprotected sectors of the population and in the reduction of the city's ecological footprint, as it uses elements considered as high entropy waste for productive ends bringing it close to new sustainability aims.

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