Chapter

Soil Quality Problems Associated with Horticulture in the Southern Urban and Peri-Urban Area of Buenos Aires, Argentina

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Abstract

Horticulture is the main productive activity of south Buenos Aires city peri-urban sector. This activity is carried out with intensive land use, based on the high use of inputs, which has generated important pollution and soil degradation problems. Soil degradation processes have their origin in the poor quality irrigation water (sodium bicarbonate) and in the indiscriminate use of fertilizers and organic fertilizers, without considering the requirements of the crop and soil analysis. The results of a large number of surveys in the area, specified in the following chapter, showed salinization, pH increase, structure quality loss, organic matter decrease and phosphorus hyperfertilization. On the other hand, urban gardens are increasingly common, that is, the production of vegetables for own consumption within the urban framework. In this case, the problems are related to the type of soils where it occurs, and they are in general highly modified lands that almost completely lost their natural characteristics and are usually not favorable for plant growth. The results from the cases studied in La Plata city showed that urban soils have low organic carbon content, high bulk density and high pH. In these soils, the horticultural production with agroecological base managed an increase in the organic carbon content and a decrease in the apparent density.

Keywords: soil quality, anthropic soils, agroecology, overfertilization, soil degradation

1. Introduction: characteristics of the horticultural sector

Argentina has a continental area of 2.8 million km^2 from which about 34 million hectares are destined to agricultural crops production. Vegetables and legumes production occupies only 1.5% of that total; however, it represents 10% of the gross agricultural product [1]. Horticulture is characterized by its high degree of intensity in the use of land, labor, capital and technology, so it has social importance and generates a large number of jobs [2]. On the other hand, because this activity is carried out in every province of Argentina, it has importance from a geopolitical and strategic point of view, being part of the "regional economies" [1].

The wide distribution of horticulture in Argentina is due in part to the diversity of climates that it possesses, however the commercial production that supplies the main urban centers with fresh vegetables is located in the peripheral area of those urban centers (peri-urban). The peri-urban is represented by an area of small farms and orchards in the surrounding of large cities, which production is specialized in leafy vegetables and seasonal vegetables. Therefore this area is commonly referred to as the "green belt" [3]. The green belt of Buenos Aires city has more than 5.510 km^2 and includes a population of more than 4.5 million habitants. This area is represented by the districts of La Plata, Florencio Varela, Berazategui, Almirante Brown, Esteban Echeverría, La Matanza, Merlo, Moreno, Cañuelas, General Rodríguez, Luján, Marcos Paz, Pilar and Escobar. The three most important districts in terms of horticulture are in the southern peri-urban of Buenos Aires city (La Plata, Berazategui and Florencio Varela) (**Figure 1**). These districts represent 82% of the total horticultural farms and 81% of the surface under cultivation [5]. This is one of the most important areas for fresh food production (refer to leafy vegetables or flowers, fruits and stems); therefore, horticulture is very important in the local economy.

Horticulture in the southern green belt of Buenos Aires city is characterized by having an intensive and highly diversified production scheme in terms of production systems and diversity of species cultivated. The largest area in hectares is under open-field cultivation systems, however most producers have a combination of both open-field and greenhouse cultivation systems. The total area of the southern green belt under vegetables production is 5332.8 ha, with 30% under greenhouses cultivation systems and the rest in open-field cultivation systems [4]. Although there is a marked heterogeneity of producers, small and medium-sized enterprises, mainly from family farming, stands out. However, there are also a small number of business-type productions with mainly hired labor. Approximately 70% of producers rent small areas of land (smaller than 5 ha) and can have 1–1.5 ha under greenhouses [6]. Only half of the producers have technical advice mostly from

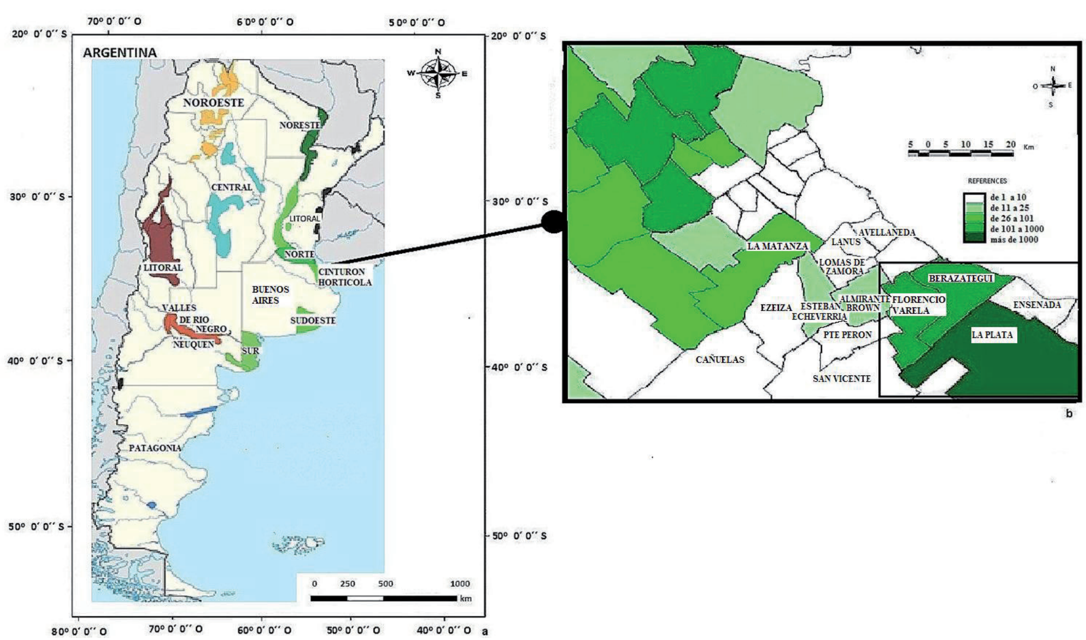

Figure 1.
(a) Argentinian horticultural regions. (b) Buenos Aires metropolitan districts that integrate de Green belt. References indicate the number of farmers per district. Source: [1] and Censo Hortiflorícola de Buenos Aires [4] Ministerio de Asuntos Agrarios—PBA. The boxed area indicated the sampling area (Florencio Varela and La Plata).

private sources, and to a lesser extent from public sources [1]. The main vegetables grown in greenhouses are: (in order of importance) *Solanum lycopersicum* (tomato), *Spinacia oleracea L.* (spinach), *Lactuca sativa* (lettuce), *Capsicum annuum* (pepper), among others of minor importance. The main vegetables grown in the open-field are: *Lactuca sativa* (lettuce), *Beta vulgaris var. cicla* (chard), *Spinacia oleracea L.* (spinach), *Solanum lycopersicum* (tomato), *Capsicum annuum* (pepper), *Cucurbita pepo* (trunk zucchini), *Brassica oleracea var. italica* (broccoli), *Brassica oleracea var. capitata* (cabbage), among others [7].

2. Climate and soil in the southern Green belt of Buenos Aires

The climate is mild without a dry season, with hot summers and mild winters. The average annual temperature is 16°C and the frost-free period is of 220 days (from October 20 to May 10). With the expansion of greenhouses, the influence of climatic conditions has diminished, however, the extreme temperature, high air relative humidity and the excess or deficit of light represent climatic limits for this production system. The total rainfall in the area is between 900 and 1000 mm a year and is distributed more or less uniformly in the four seasons. The water used for irrigation is extracted from between 55 and 60 m deep in each farm [1]. Generally the irrigation system is drip irrigation (20 cm between drippers, with two irrigation hoses per spine) and fertilization is performed by fertirrigation [8].

With respect to geomorphology, the southern green belt is characterized by gentle undulations of long and not very steep slopes. The area that encompasses the southern urban and peri-urban area is crossed by streams that run through it and drain into two basins: the Río de la Plata and the Samborombón and the Salado rivers. Between these basins there is a quite elevated terrain that separates their drainage.

The types of soil that predominate vary with the origin of their primary materials. In the higher areas, lithologically, the original materials belong mostly to the

Soils characteristic	La Plata	Florencio Varela
BD (g cm^{-3})	0.96	1.08
AS (MWD)	2.29	2.57
Soil texture	Clay loam-silty clay loam-silty loam	Silty clay loam-silty loam
pH	7.15	6.96
CE (ds m^{-1})	0.21	0.16
TOC (%)	2.86	3.21
POC (%)	0.24	0.73
MOC (%)	2.62	2.48
TN (%)	0.38	0.33
EP (mg kg^{-1})	81.40	80.26

BD: bulk density by cylinder method [15]; AS (MWD): aggregate stability (mean weight diameter) [16]; Soil texture: clay, sand and silt percentage (USDA triangle); pH and EC: electrical conductivity in water 1.2.5 by potentiometry [17]; TOC: total oxidative carbon by Walkley and Black [18]; MOC: oxidative carbon associated with the mineral fraction; POC: particulate oxidative carbon [19]; TN: total nitrogen by Kjeldahl micro-method [20]; and EP: extractable phosphorus by Bray and Kurtz 1 [20].

Table 1.
Peri-urban soils characteristic in non-cultivated sites.

"pampean sediment" consisting of sand-clay silt with limestone (loess). However, the limestone is not present in the upper horizons due to washing. Properties as pH, organic matter and soluble salts make these soils suitable for agriculture. In addition, due to their topographic condition they are not affected by floods [9]. Most agricultural soils in the southern green belt belong to the Molisol and Vertisol orders [10] (Chernozems and Vertisols) [11]. They have a strong profile development with dark A horizons, generally thick and well provided with organic matter followed by B horizons enriched in eluviated clay accompanied, especially in Vertisols, by evidence of expansion and contraction of materials. These are soils with high cation exchange capacity given by both organic matter and clay content. From the physical point of view, high levels of clay and silt, makes them susceptible to changes in their physical properties. In some cases there is low permeability and high plasticity in B horizons.

Low permeability is the main physical limitation for soils management in this area being more pronounced in the district of La Plata, where Vertisols with high clay content in surface (between 32 and 40%) and depth (50–60%), prevail. The only chemical limitation is low P content (less than 10 mg kg^{-1}) [12]. However, [9] reported 20.7 mg kg^{-1} in soils from natural fields. Moreover, [13, 14] studying the surroundings of La Plata reported levels of extractable P greater than 20 mg kg^{-1} in soils that were not under agriculture for at least the past 20 years. **Table 1** describes some physical and chemical properties of soils around the houses of horticultural farmers from the southern green belt of Buenos Aires city.

3. Traditional horticulture in the southern Green belt of Buenos Aires

Horticulture depends on the soil; therefore the conservation of this resource is essential to ensure the development of the sector. The intensive use of the soil, based on the overuse of inputs for many years (fertilizers, pesticides, disinfectants), added to irrigation with low quality water (sodium bicarbonate) [21], has generated negative impacts associated with soil pollution and degradation. The alteration of soil physical, chemical and biological properties resulted in a fragile productive system with a high risk of environmental impact [22, 23].

Soil physical condition establishes its sustainability, root penetration, air circulation, water storage capacity, drainage, nutrient retention, among other factors. The texture (proportion clay, silt and sand) determine the amount and availability of water, nutrients, aeration and drainage. Soils with fine texture (clay more than 40% or silt more than 60%) have a high water and nutrient retention capacity. However, it must be handled with caution because they are easily compacted. Likewise, crops sensitive to soil pathogens are more susceptible in heavy textured soils. Fertirrigation has counteracted these disadvantages. Soil compaction reduces porosity and increases its bulk density. This limits the space for the storage or movement of air and water within the soil. It is the cause of a physical restriction for the germination and radical growth of crops. Low values of organic carbon, high humidity and fine textures are more susceptible. The appropriate values for the growth of any plant with these textures must not exceed 1.1 g cm^{-3}. Furthermore, a good structural stability helps keep particles together against different destabilizing forces that can act on a soil. Soil chemical condition like pH influences nutrient availability and soil microbial activity. In acid soils, few nutrients are available to be taken by the roots. Suitable values for horticultural crops are between 6 and 7.5 depending on the crop. The electrical conductivity determines the concentration of soluble salts present in the soil solution and can affect germination, plant growth or water absorption. Each crop has a different capacity to support soil salinity without experiencing detrimental effects on its development and production (tolerance). The organic carbon brings life to the soil, is a nutrient reserve, improves its physical conditions, improves soil structure and its porosity, increasing the aeration and water circulation that favors the development of the plant, regulates microbiological activities; privileges infiltration, decreasing soil erosion, improving soil water balance, tends to reduce evaporation and is a water reservoir. Well-supplied soils have carbon values between 4.5 and 6.5% [24].

The main degradations observed are edaphic salinization and alkalinisation, which are associated with waterlogging, development of pests and nutritional imbalances [13, 25–27]. These observations are partially coincident with those reported for other regions of the country [28] and the world [29–31].

Soils management and the use of groundwater for irrigation, do not often consider local properties, but are mainly based on information obtained in other parts of the world with characteristics very different from those described in the area of study. In general, there is a lack of knowledge and awareness of the processes involved in soil, air and water pollution. Producers from the southern green belt do not perform soil analysis prior to sowing or fertilizing, the quality of the irrigation water is unknown and soil management is performed based on the particular experience of each producer [1]. In many cases a "fertilization recipe" is applied without considering the physicochemical characteristics of the soil of each farm and without considering the nutrient demand of the crop [32].

Salts and sodium accumulation is exacerbated in soils with higher clay content since in these cases drainage is limited and therefore salts are not eluviated. Comparing 17 soil samples, obtained randomly from not cultivated sites (NC) placed within the horticultural farms (e.g., areas adjacent to the houses), in two districts from the southern green belt, it was found that soils from the district of La Plata (with higher clay content on the surface horizon) had higher electrical conductivity compared with soils from Florencio Varela (**Figure 2**). The crops present in the most of the sampled soils were chard, lettuce, onion, crucifixes and zukini.

Likewise, salinization is also exacerbated in greenhouse cultivation systems with respect to open-field cultivation systems. In greenhouses, the excessive application of fertilizers, the use of low quality water with high content of sodium bicarbonate for irrigation, evapotranspiration that favors the accumulation of salts on the surface and the impossibility of washing with rainwater, further complicates the situation. Formerly, it was a common practice to remove the ceilings of the Greenhouses, made of glass, and allow the soil to be "washed" by the rain. Nowadays, this practice is less frequent, mainly because the cover of the greenhouses has been changed from

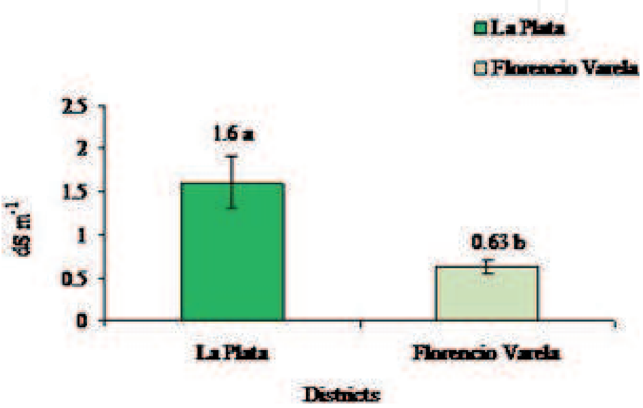

Figure 2.
Soil electrical conductivity in not cultivated soils per district. EC: electrical conductivity in water 1:2.5 by potentiometry [17]. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey ($p < 0.05$) [33].

glass to plastic [13]. Thirteen soil samples were randomly obtained from horticultural farms from Florencio Varela district and it was observed that the electrical conductivity was higher in greenhouses than in open-field cultivation systems (**Figure 3**).

Although the electrical conductivity levels found in this study are still adequate for the growth of most horticultural species, some of them are at the limit. Vázquez and Terminiello (2008) found that saline concentrations greater than 1.2 ds m^{-1} affect the development and, consequently, the yield of onion, with a production reduction of 16% for every additional ds m^{-1}. Moreover, an adequate electrical conductivity should not exceed 1.5 ds m^{-1} for pepper [34] and 1.5 ds m^{-1} for tomato [35, 36]. [8] in a study carried out in greenhouses from La Plata district, found a high number of sites with high salinity levels with extremes that reached 10.6 ds m^{-1}. Under salinity conditions, there is a nutritional imbalance, due to different factors such as nutrient availability and competitive absorption.

Alkalization also represents an important problem in horticultural production. Cultivable soils from the southern peri-urban are naturally neutral or slightly alkaline but their alkalinity increases with horticultural use [9, 37]. Soils from the southern green belt were studied and it was observed that cultivated soils have higher pH, in both open-field and greenhouse cultivation systems, in comparison with non-cultivated soils.

It is important to consider that under high pH levels the availability of certain nutrients will be diminished, affecting crop development [38]. pH levels found in this study exceed the tolerance thresholds for many of the horticultural species grown in the southern green belt [39]. In this regard, [40] established that high pH levels (greater than 8) decrease the absorption of P and Ca^{+2} by crops, and on the contrary increase that of Mg^{+2}, because the absorption of its competitive elements diminishes. Increases in pH and electrical conductivity in cultivated soils compared to uncultivated ones are mainly linked to the quality of the water used for irrigation. **Table 2** shows results from irrigation water analysis, sometimes also used for human consumption. The samples were taken from horticultural farms from the southern green belt of Buenos Aires. The results show that in addition to the low quality in terms of physicochemical characteristics, water samples have also microbiological contamination with faecal bacteria. This usually happens due to the high number of improperly drilled holes that cause leaks from nearby blind wells. Inadequate water management brings associated problems such as lower

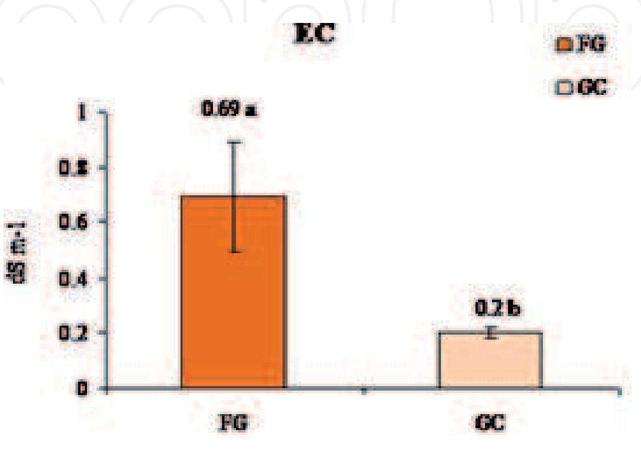

Figure 3.
Electrical conductivity values per system. EC: electrical conductivity in water 1:2.5 by potentiometry [17]; FC: open-fields cultivation systems; GC: greenhouses cultivation systems. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey (p < 0.05). [33].

Well depth	Count		Investigation		Nitrites	Nitrates	pH	EC
m	MAB u.f.c. ml^{-1}	TC NMP 100 ml^{-1}	*E coli* in 100 ml	PA in 100 ml	ppm	ppm		μs cm^{-1}
60	40	5.1	+	0	0.01	50	8.4	810
50	75	16.1	+	0	0.01	50	7.8	870
75	185	5.1	+	0	0.01	50	7.9	850
30	70	3	0	0	0.01	100	8.4	1240
76	30	16.1	0	+	0.01	25	8.1	730
Drinking water quality	Maximum 500	Maximum 3	0	0	Maximum 0.10	Maximum 45	6.5–8.5	Maximum 400*

MAB: mesophylls aerobic bacteria; TC: total coliforms; E. coli: Escherichia coli; PA: Pseudomonas aeruginosa; +, presence; 0, absence; pH: pH in water 1.2.5 and EC: electrical conductivity in water 1.2.5 by potentiometry [17]. References levels for drinking water quality according to CAA [41].
**of secondary importance according to CAA [41].*

Table 2.
Irrigation water characteristics.

productivity, lower product quality, higher disease incidence, higher energy use and lower efficiency in the use of water and fertilizers [42].

High pH levels in the irrigation water are due to the fact that it has sodium bicarbonate. When irrigating with this water, the sodium cation is concentrated in the soil, generating an alkaline reaction. Another problem, not less important, associated with the presence of sodium (Na) in the soil is the effect that this cation has on soil structure. Soils with high exchangeable sodium content have dispersed colloids and therefore an unstable structure. Moreover, soil crusts are formed that seal the surface, creating or magnifying the problems of fluid exchange and impedance for plants (seedling emergence) and biological activity. The accumulation of dispersing cations such as Na^+ causes expansion and/or dispersion of clays, which alters the geometry of the pores, in turn affecting the permeability and retention of water in the soil [38].

Studying soils from the southern green belt, a decrease in aggregate stability (AS) was found in cultivated soils, both under open-field and greenhouse cultivation systems, compared with uncultivated soils from house surroundings. Samples were analysed using the Le Bissonnais [16] technique that assesses structural stability by calculating the mean weight diameter (MWD) of soils aggregate afte r being subjected to three pre-treatment conditions to determine the dispersive effect of different processes. Thus, T1 aims to show how dry soil behaves in the face of heavy rain, T2 how wet soil behaves in the face of intense rain and T3 how dry soil behaves in the face of mild rain and therefore a slow humidification. Uncultivated soils presented higher aggregate stability after every pre-treatment, with the average index (AVE I) of aggregate stability of 2.47 for uncultivated soils and 1.1 for cultivated soils (**Figure 4**).

In addition, an increase in pH was observed in cultivated soils (**Figure 5**). **Table 3** shows the correlation found between aggregate stability and pH in soils from the southern green belt.

In the same study, when bulk density was analysed, no significant differences were found between cultivated and uncultivated soils (**Figure 6**). This is probably linked to the fact that the sampling was performed after soil tillage was carried

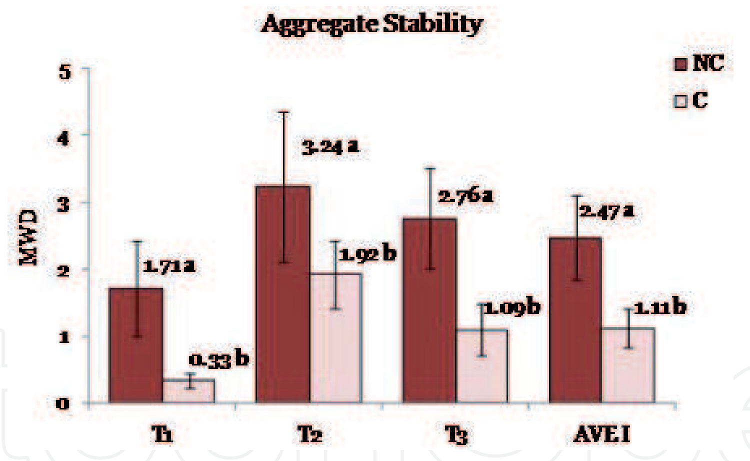

Figure 4.
Aggregate stability by Le Bissonnais method [16]. MWD: mean weight diameter; C: cultivation sites; NC: not cultivated; T1: dry soil behavior in the face of heavy rain; T2: wet soil behavior in the face of heavy rain; T3: dry soil behavior in the face of mild rain; AVE I: average index of the three pretreatments. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey ($p < 0.05$) [33].

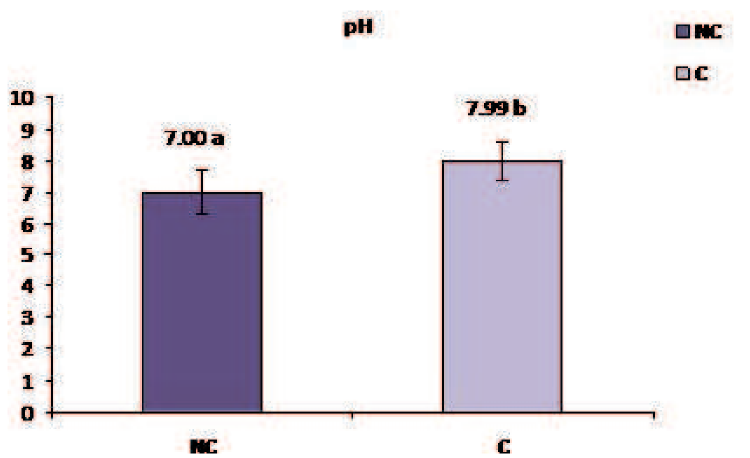

Figure 5.
Soils pH values. pH: pH in water 1: 2.5 by potentiometry [17]; C: cultivation; NC: not cultivated sites. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey ($p < 0.05$) [33].

	T1	T2	T3	AVE I	pH
T1	**1**				
T2	0.66	**1**			
T3	0.91	0.73	**1**		
AVE I	0.95	0.79	0.97	**1**	
pH	−0.75	−0.44	−0.7	−0.7	**1**

T1: dry soil behavior in the face of heavy rain; T2: wet soil behavior in the face of heavy rain; T3: dry soil behavior in the face of mild rain; AVE I: average index of the three pre-treatments [16]; pH: pH in water 1.2.5 by potentiometry [16]. Significant correlations are presented with $p < 0.05$ [32].

Table 3.
Pearson correlation coefficients (r) between pH and aggregate stability treatments.

out in cultivated soils. Soil crusting and compaction due to structural instability leave producers with no options but to increase pre-sowing tillage to ensure crops emergence and growth. This causes greater aggregates destruction and formation of a plow floor that require re-tillage the soil generating a vicious circle that also increases production costs due to the high fuel use required for tillage tasks.

This instability of the production system causes, a few years after the start of production, the decrease in crop yields due to land degradation linked to the interconnection of the following problems: salinization, alkalization, decreased permeability, flooding, nutritional imbalances and development of diseases. To counteract the negative effects crop yields and without performing the appropriate analysis, fertilization doses are increased, adding soil hyperfertilization to the aforementioned problems [26] and increasing costs of production and environmental damage [37, 43].

It is common to try to reverse the decrease in yield by increasing the addition of fertilizers and phosphoric acid. Occasionally, there is a favorable initial response of the crop to greater fertilization, generating the wrong idea that it effectively contributes to improving the productive environment. However, eventually over fertilization occurs, and the problems associated with land degradation are exacerbated [21, 43] since these practices do not alleviate pH imbalances in a sustained manner and, on the contrary, they generate a negative effect due to the excessive accumulation of P (greater than 300 mg kg^{-1}) leading to nutritional imbalances and contamination [14, 43, 44]. With such high concentrations of P in the soil there is no response to fertilization [45] in addition, the availability of P not only depends on chemical fertilization, but also on the response or interaction with Ca^{+2}, Mg^{+2}, Al^{+3}, Fe^{+3} and Mn^{+2} [46]. Thus, in high pH situations, P forms insoluble compounds with Ca^{+2} and Mg^{+2} [45], leading to induced deficiencies. This has also been reported in other parts of the world with negative consequences on the environment, production and economics [47].

Figure 7 shows extractable P levels by Bray and Kurtz 1 found horticultural farms from the southern peri-urban. Sampling sites included soils under open-field and greenhouse cultivation systems and uncultivated soils adjacent to the houses. The range of extractable P concentrations varied from 50.7 to extremely high levels as 538.7 mg kg^{-1}, with an average of 255.0 mg kg^{-1}. It is also observed that the minimum levels obtained from cultivated sites double the maximum level from uncultivated sites. It is also interesting to note that the levels found in uncultivated sites are well above what soils should have in their natural state [9, 12, 34], so it could be hypothesized that such high P contents, would exceed soils retention capacity, therefore remaining in solution and being able to reach uncultivated sites from adjacent cultivated areas. In this sense, [48] reported contamination of a river basin in the southern peri-urban area with P derived from the horticultural activity.

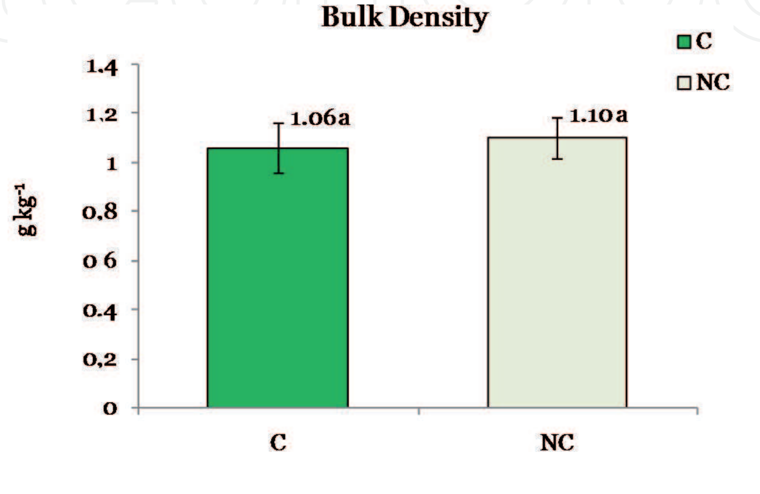

Figure 6.
Bulk density values. BD: bulk density by cylinder method [15]; C: cultivation sites; NC: not cultivated. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey (p < 0.05) [33].

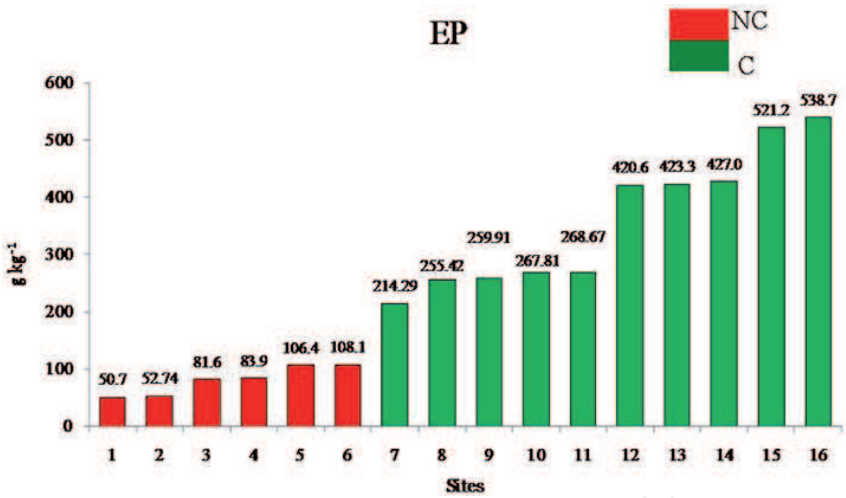

Figure 7.
Extractable phosphorus values in C: cultivated and NC: not cultivated sites. EP: extractable phosphorus by Bray and Kurtz 1 [20].

At present, there are few works that analyse the changes in the P content of the soil due to horticulture or that explain the causes of such accumulations of P in uncultivated sites in the area.

Another horticultural practice proposed as a possible solution to degradation soil but ended up generating major problems, is the use of poultry litter as organic fertilizer. This organic amendment is widely used in the area to improve the organic matter content of the soil and thus improve its structure; however, its excessive application is a potential source of soil and water contamination. In addition to providing nutrients, these fertilizers introduce salts and pollutants into the soil and, in general, these poultry litters are characterized by having high pH, high electrical conductivity and high P content, which contribute to worsen the aforementioned problems. These materials are very variable in their composition and therefore should be analysed prior to soil application. As an example, when analysing a poultry litter sample from a supplier from the area under study, pH levels found were between 7.6 and 8.6; electrical conductivity values between 3 and 7.8 dS m^{-1}, TOC between 34 and 45%, total N content between 2.08 and 2.42% and the C/N ratio between 16.3 and 18.6%. The extractable P content found ranged between 1600 and 3900 mg kg^{-1} and total P between 6500 and 12,000 mg kg^{-1}. Other authors have reported average total P content of 8700 mg kg^{-1} [25], although concentrations higher than 10,000 mg kg^{-1} have been detected in poultry litter and poultry manure [49, 50]. These characteristics depend on the composting time and the climatic conditions during composting. A poultry litter supplier usually sells to several horticultural farms of the area.

However, beyond all the negative characteristics of the poultry litter, some authors have proposed the use of these organic amendments as a promising practice to improve or mitigate the impact of horticultural production on the soil [51, 52]. An important process that is undergone in the horticultural soils under study is the progressive loss of organic matter [53]. [54] argue about the advantages of poultry residues and underline that they not only contribute with significant amounts of nutrients but also organic matter, which has a favorable effect on soils structure and permeability which is usually limited in the green belt area. However, other authors claim that the addition of poultry litter does not lead to significant increases in total oxidative carbon (TOC), since organic humus-forming materials are those of plant origin [26, 55]. The labile fractions of organic matter, such as those represented by the particulate oxidative carbon (POC), are much more sensitive to changes in management practices. Therefore, when a change in practices is made, the dynamics of these fractions are altered, affecting the physical, chemical and biochemical

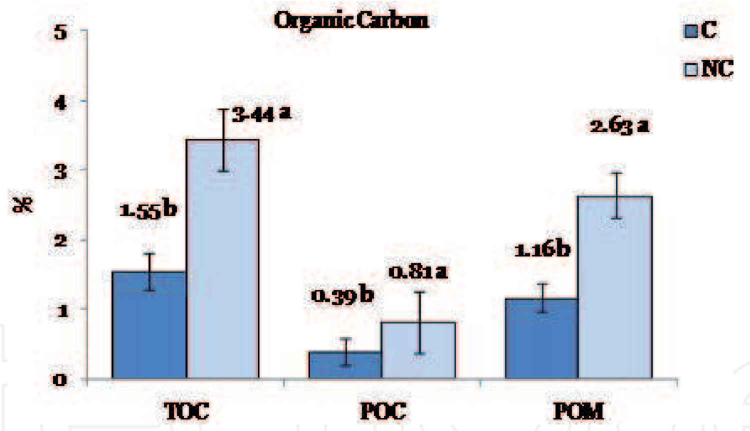

Figure 8.
Organic carbon fractions. TOC: total oxidative carbon by Walkley and Black [18]; MOC: oxidative carbon associated with the mineral fraction and POC: particulate oxidative carbon [19]. Vertical bars indicate the standard deviation. Different letters show significant differences between treatments according to Tukey (p < 0.05) [33].

environment of the soil [56]. Oxidative carbon associated with the mineral fraction (MOC) corresponds to a more complex and stable humus, which requires more time for its formation, making it difficult to increase its content through agricultural practices in the short term.

Figure 8 shows the results obtained from soils sampled in horticultural farms from the districts of La Plata and Florencio Varela where poultry litter is applied regularly every year, in some cases on more than one occasion. In the present study, the contents of TOC and MOC were lower in cultivated sites than in uncultivated sites. In addition, it should be noted that the POC was also lower in cultivated sites, indicating that the addition of poultry litter is not enough to counteract the loss of organic carbon associated with horticulture, not even those fractions of rapid cycling. Similar results were found by [8, 57].

4. Horticulture in the city

In the last years and in different parts of the world, the way the city is inhabited has been transformed; the daily relationship between human beings and their natural environment within the city has changed [58]. During the twentieth century, urban agriculture reached a great development due to increasing urbanization, deterioration of life conditions in poor neighborhoods, wars, natural disasters, environmental degradation and lack of resources, which caused food shortage. Urban agriculture means food production within the cities, in most cases it is a small-scale activity scattered throughout the city [59]. The large number of community horticultural gardens located in charitable dining rooms and in vacant spaces (for example, under high-voltage lines or along roads and waterways), or in institutional spaces such as hospitals and businesses, family gardens in backyards and roofs and school gardens are just a few examples that show the growing presence of agriculture in the cities [60].

Food production within the city is mainly used for self-consumption, to improve the amount of available food, for its freshness, variety and nutritional value [61], for environmental education and the exchange of experiences, among other factors, as [62] points out. It is also associated with jobs generation and income for groups of individuals, and it promotes environmental sanitation through the recycling of organic waste [63]. As it is a multifunctional and multicomponent activity, urban agriculture can respond to a great diversity of urban issues that include from the fight against poverty and the strengthening of self-esteem, to the improvement of the urban environment, participatory governance, management of the territory and food and nutritional security [60].

5. Front of organizations in fight (FOL) cooperatives: a case study

In Argentina, after the political-economic crisis of 2001, movements of unemployed workers were formed, including the FOL. Within these movements labor cooperatives were developed. One of the activities performed in a cooperative way is horticulture, which is carried out in community gardens located within popular neighborhoods, many of them developed in poor settlements. The majority of the production of these gardens is destined to the neighborhood dining rooms; therefore they are an important component improving the diet of hundreds of families, who otherwise only ingest carbohydrates and canned food. In turn, these spaces serve as a reference for the entire neighborhood and encourage exchange and knowledge between neighbors. Therefore, self-sustaining neighborhoods are generated with less garbage, different exchange relationships, and healthier food. However, horticultural gardens located in these popular neighborhoods often have one main problem; they were developed on soils highly modified. Urban soils or "anthropic soils" have been disturbed profoundly by human activity through the mixing, importing and exporting of materials [64, 65], and they are often characterized by contamination, compaction and soil sealing, as well as deposition, and removal or mixing of natural substrates. Soils in the urban environment tend to be very disturbed because of surrounding human activities and might even be exogenous (i.e., transported from elsewhere) [66, 67]. Therefore, the properties of urban soils are normally not favorable for plant growth and their role in food production is compromised [68].

Soils from horticultural gardens developed in poor settlements from La Plata city, were sampled during 2018 and 2019. Site 1 corresponds to "Barrio Altos de San Lorenzo," which is located on an old landfill pit that has received the contribution of the surrounding stream, Site 2 and 3 are located in "Barrio el Carmen," built on top of material dragged from the bottom of the Maldonado stream (**Figure 9**).

The most outstanding characteristics of these soils were: moderate bulk density, high pH and low TOC content (**Table 4**).

These conditions necessarily involve the application of soil recovery management practices in the horticultural gardens. In this sense, agroecology proposes soil management strategies that can contribute to improve their productive properties. To guarantee the success of the popular gardens within the same organizations, workshops and training for agroecological production are given. The gardens are fertilized with compost that is obtained from compostable household waste. Moreover, crop rotation and crops associations are considered to improve nutrient balances and aromatic species that serve as insect repellents are sown. Agroecology takes advantage of the natural processes of interactions that occur in an horticultural field in order to reduce external inputs (many of them potential contaminants and toxic compounds) and improve biological efficiency of cropping systems [69].

The horticultural gardens managed by FOL cooperatives in the neighborhoods of "Altos de San Lorenzo" and "El Carmen," unlike what happens in peri-urban productions, are irrigated with water from the water supply network which is of better quality than the water pumped from wells (lower electrical conductivity and lower pH). However, given the precarious nature of these settlements, many of them are illegally occupying fiscal lands, do not have legal access to the water supply network and make unsafe connections that can become contaminated with faecal matter (**Table 5**).

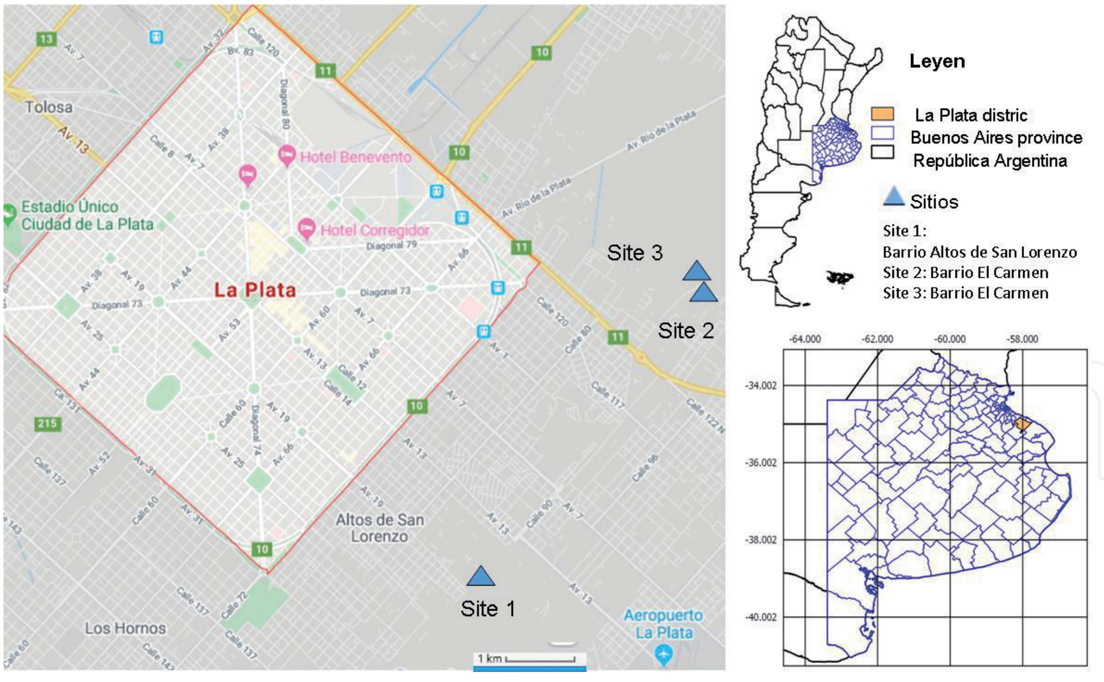

Figure 9.
Location of sampling sites.

Sites	BD g cm^{-3}	pH	TOC %	Texture			
				Sand %	Silt %	Clay %	Soil texture
Altos de San Lorenzo	1.17	7.91	0.74	27	34	39	Clay loam
El Carmen	1.28	8.70	1.14	30	28	52	Clay
Ideal scenario	Lower than 1.1	5.5–7.0	Greater than 3.5				

BD: bulk density by cylinder method [15]; Soil texture: clay, sand and silt percentage (USDA triangle); pH: pH in water 1.2.5 by potentiometry [17]; TOC: total oxidative carbon by Walkley and Black [18]. Ideal scenario: reference values for adequate crop production [62].

Table 4.
Urban soils characteristic in not cultivated sites: Altos de San Lorenzo y El Carmen.

After 3 years of agroecological production in the neighborhoods under study, soil sampling was performed and it was observed that some characteristics improved (**Figure 10**).

Bulk density diminished and an increase in TOC was observed (**Figure 10c** and **f**), these improvements are linked to the use of compost as an organic amendment in the agroecological gardens [70, 71] which not only acts as fertilizer but also improves soil physical properties [69].

Although urban soils from the popular neighborhoods studied had electric conductivity levels below the risk thresholds for any crop, this property decreased in the horticultural gardens which could be related to salts washing as a result of irrigation with non-saline water (**Figure 10b**). No improvements were found regarding total N content (**Figure 10d**), this could be explained due to the use of vegetable compost as the only fertilizer. Composting from household waste usually has low N content and high C/N ratio [72], therefore a source of nitrogen should be considered to improve soil quality, for example through the incorporation of green manure with legumes which are able to fix atmospheric nitrogen or including more

Site	Count		Investigation		Nitrites	Nitrates	pH	EC
	MAB u.f.c. ml^{-1}	TC NMP 100 ml^{-1}	*E. coli* in 100 ml	PA in 100 ml	ppm	ppm		µs cm^{-1}
Altos de San Lorenzo	100	9.2	+	+	0.01	30	6.90	973
El Carmen	Lower than 10	Lower than 3	0	0	0.01	10	6.95	1016
Drinking water quality	Maximum 500	Maximum 3	0	0	Maximum 0.10	Maximum 45	6.5–8.5	Maximum 400*

MAB: mesophylls aerobic bacteria; TC: total coliforms; E. coli: Escherichia coli; PA: Pseudomonas aeruginosa; +, presence; 0, absence; pH: pH in water 1.2.5 and EC: electrical conductivity in water 1.2.5 by potentiometry [17]. References levels for drinking water quality according to CAA [41].
**of secondary importance according to CAA [41].*

Table 5.
Irrigation water characteristics of urban sites.

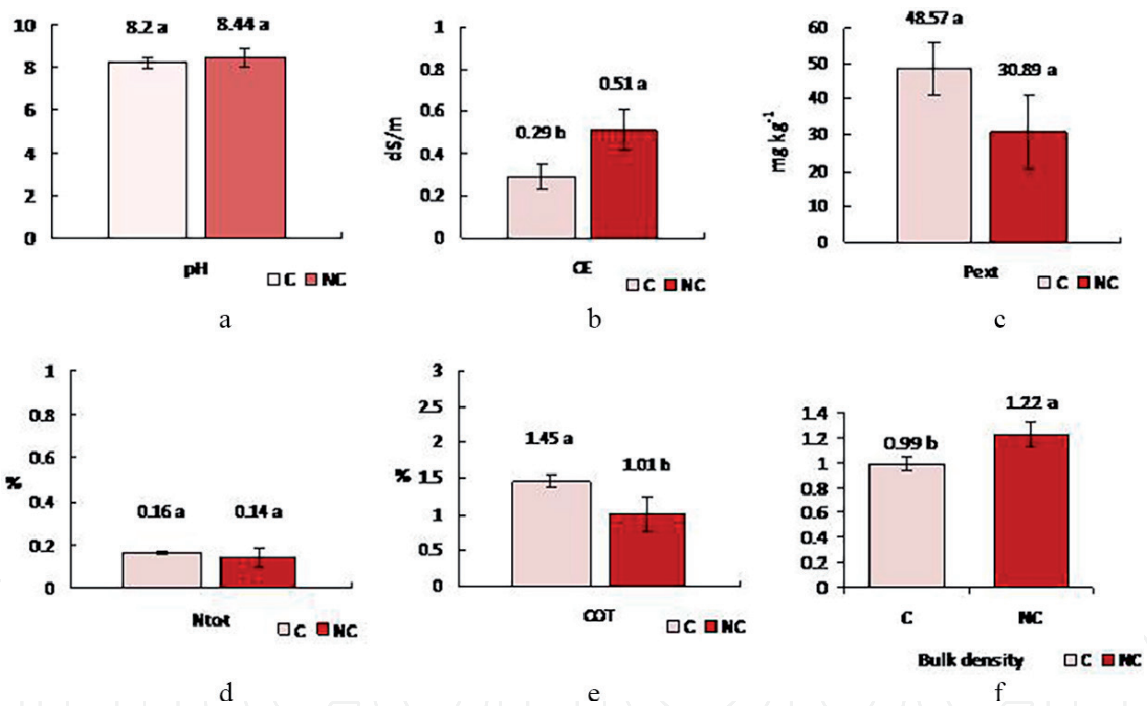

Figure 10.
(a) pH: pH in water 1; 2.5 (potentiometry) [17]; (b) EC: electrical conductivity in water 1; 2.5 (potentiometry) [17]; (c) TOC: total organic carbon (Walkley and Black) [18]; (d) TN: total nitrogen (Kjeldahl); (e) EP: extractable phosphorus (Bray and Kurtz 1) [20] and (f) BD: bulk density [15] for NC: not cultivated sites and cultivated sites (C). Vertical bars indicating the standard deviation. Different letters show significant differences between treatments according to Tukey ($p < 0.05$) [32].

legumes in crop rotation. Another property that could not be improved was pH (**Figure 10a**), which was expected, since pH is one of the chemical properties of the soil that varies the least, because it is an intrinsic characteristic of the soil genesis [73, 74]. To generate a significant change in pH, some specific corrective amendment should be applied, for example calcium sulfate.

With respect to extractable P [12, 34], reported that soils from this area, in their natural condition, are characterized by having low levels of extractable P (less than 10 mg kg^{-1}). Other studies in the southern peri-urban area reported higher values, close to 20 mg kg^{-1} in uncultivated soils [13, 14]. In this study, we worked with urban soils composed of material removed from the stream that receives runoff water from the entire basin. Phosphorus from many human activities, mainly the use of fertilizers and amendments in horticultural productions of the peri-urban area [8, 14, 26], could have been transported dissolved along with the runoff water and be retained in the clays [44] of the stream bed material that was subsequently used to build the urban soils of some settlements. This could be the reason why high levels of extractable P were found even in uncultivated soils from popular neighborhoods (**Figure 10e**).

Although this section aims to show how urban land can be improved for food production, it is important to take into account some sanitary characteristics of the material on which food is grown, such as knowing the content of heavy metals which are commonly raised in urban soils.

6. Conclusions

Horticultural soils from the green belt of Buenos Aires are showing alarming signs of physical, chemical and biological degradation as a consequence of inappropriate management practices applied since many decades ago. The most important processes associated with soil degradation in this area were salinization and alkalization principally as a consequence of irrigation with water with high levels of sodium bicarbonate and excessive application of organic amendments. The mentioned processes are also associated with nutritional imbalances and the loss of soil structure. Soil structure is also negatively affected by the loss of soil organic matter, usually observed in intensive agricultural systems as horticulture, which is not being compensated by organic amendments. On the contrary, the use of organic amendments and inorganic fertilizers indiscriminately, without performing the appropriate previous soil analyzes, or considering the needs of the crops, generates an over fertilization that increases the risks of nutritional deficiencies and could cause environmental damage due to nutrients leaching to underground water and superficial water courses. Particularly, there is a need for research on the dynamics of phosphorus since, although this element is considered immobile, the concentrations found in the soils of the area are so high that they could exceed the retention capacity of the soils and generate important environmental impacts at the basin level. Therefore, given the problems described in this chapter, it is necessary and urgent to change the productive paradigms if the intention is to ensure food production in the most important horticultural sector of the Argentine Republic. Soil is a non-renewable natural resource, its use and management must be integrated in a long-term perspective within a sustainable development approach; within a sustainable agriculture. Agroecology gives a new approach to the agricultural system, trying to provide solutions based on the interactions of physical, biological and socioeconomic components of the systems, integrating knowledge in the local and regional level to ensure sustainable production. Urban horticulture in Argentina is being developed mainly under an agro-ecological perspective. Although production within cities covers a much smaller area and of less economic importance than peri-urban horticulture, it is a role model, generating information from multiple local experiences that can serve as a basis to change large-scale horticultural production systems. The challenges that appear in urban production systems with an agro-ecological perspective are related, among other things, to the difficulties of producing in unnatural soils. In these soils, it is compulsory to perform quality analysis, treatment and transformation to ensure a healthy and sustainable production.

The search for agro-socioeconomical sustainability and new production system paradigms are the greatest challenges of modern agriculture, which involves among other technological practices, and adequate soil management.

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