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ARTICLE

Land Recycling, Food Security and Technosols

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ABSTRACT

The world population will grow up to 9.8 billion by 2050. The intensification in urban growth will occur on all continents and in all sizes of cities, especially in developing countries, experiencing a greater rising in urban agglomerations of 300,000 to 500,000 people, those of 500,000 to 1 million and those of 1 to 5 million, by 2035. In this way, the demand of soil to host human activities (land take) will increase, mainly affecting soils with greater agricultural potential close to cities, at the same time as the need for food will increase. Land rehabilitation can contribute to human food security, to enhance ecosystem services and, if made by waste Technosols, those are viable as substrate for urban agroforestry systems. Although the references for brownfield reclamation for urban agriculture, adding constructed Technosols and de-sealed soils can recover its ecosystem functions even food supply services and would be the solution in urban areas.

1. Introduction

Trend of rising population and number of urban settlements around the world increases pressure on land take [1-3]. Consequently, it is a challenge for coming decades, related to fertile soil conservation, provision of ecosystem services and biodiversity [1,2]. Mainly due to loss of fertile agricultural soils, compromising their role as biomass producers.

In addition, land take implies in most cases soil sealing for the expansion or development of new urban settlements [2]. Therefore, the loss of soil functionality and its ability to provide ecosystem services is further aggravated. To counteract these shortcomings, the EU promotes land recycling prior to land taking. Since this practice is currently a minority in Europe [1] and many other parts in the world, we analyze whether sealed soils or brownfields can become functionally valid even as biomass producer (urban forestry areas).

In this sense, it is important to consider that soil, a finite resource, is one of the most important stores of carbon to combat global warming and at the same time [4,5], basic for human health.

Therefore, the purpose of this work is to know if loss of ecosystem services (including food provision) associated with land take on agricultural land due to urban expansion, can be counterbalanced with land rehabilitation as a solution that can be applied in many countries but

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especially in developing countries and those with great percentage of soil sealed (i.e., in Europe). This rehabilitation can be of special interest in brownfields and by using made by wastes Technosols [5], and de-sealing soils.

2. Methodology

An analysis of literature related to consequences of population growth on arable land occupation, on ecosystem services provision and options to compensate this land take was done. This study is based on the need to determine if there is a qualitative relation between people, urban and soil sealing and try to improve the interest of administrations and research community about the problems associated to soil sealing and the solutions that can be applied.

For this purpose, internet search engines and scientific reference databases were used. The analysis was based on looking for the following key words (in the first step): population growth, agricultural land take, soil sealing, unsealing, de-sealed, de-sealing, brownfield, land recycling, brownfield, orchard, allotment garden, community garden, urban agriculture, Technosols, germination crops, food security. After that, a detailed study of the results was done, literature selected and complemented with the reports on Official Institutions websites mentioned in the reference section.

Population and settlement data were collected and processed by using dynamic tables and graphs in Excel (Office, ©Microsoft) and IBM® SPSS Statistics.

3. Urban Growth and Soil Sealing

The world's population in 2020 reached 7.7 billion people, and it is expected to continue increasing to 8.9 billion in 2035 and 9.8 billion in 2050 [6]. Considering the continents, it is expected an increase for all except Europe, which will experience a slight decline towards 2050 (Figure 1).

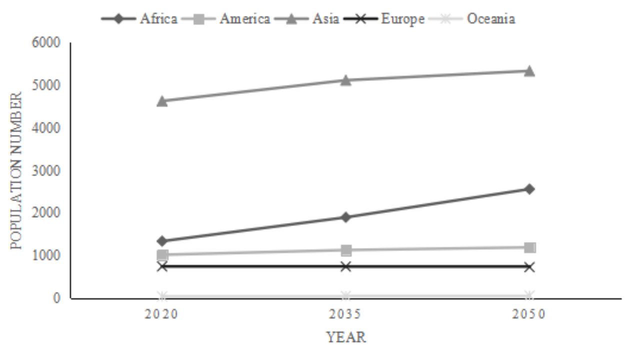

Figure 1. World population trends per continent expressed in millions of people (PRB, 2020).

Analyzing the settlement preferences of the world population in 2020, 56% choose urban environments for the development of their lives, which in quantitative terms is 4,353 million people. The urban population rate varies widely between continents and countries. Thus, in 2020, Asia is the continent with the largest urban population (2,359.26 million people), followed by America (815.2 million), Africa (575.34 million), Europe (560.25 million), and Oceania having the lowest number of urbanites (29.24 million people) [6]. The number of urban settlements also shows upward trends. In 2020 there are 1,934 registered cities around the world, and by 2035 it is estimated that they will increase to 2,363 [7], housing a population of 5,555 million people in 2035 (Figure 2) [8].

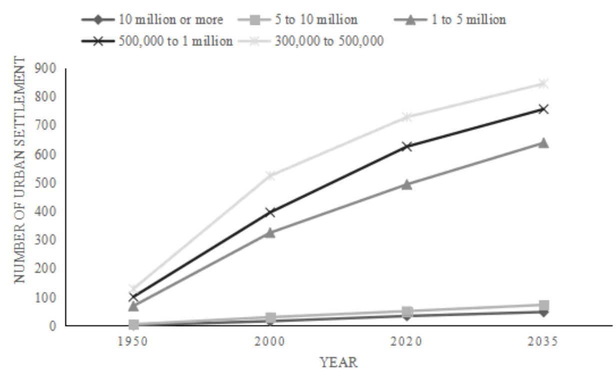

Figure 2. Number of world urban settlement trends (source: UN-HABITAT from UNDESA, 2020).

The intensification in urban agglomerations will occur on all continents and in all size of cities (Figure 3), although the increase in megacities (more than 10 million) is a phenomenon mainly associated with the Asian continent, which will increase from the current 21 megacities up to 32 megacities in 2035 [8].

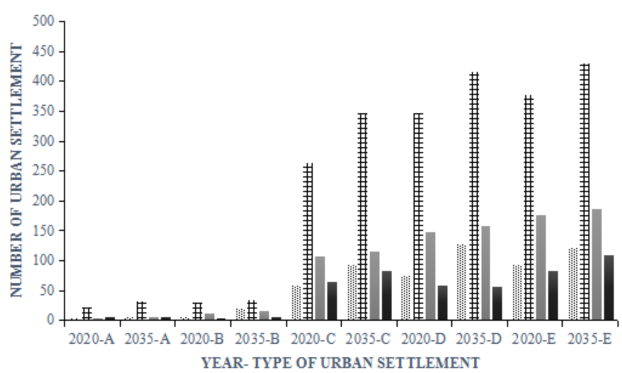

Figure 3. Continent type of urban settlement trends (2020-2035). In the figure, A: means urban settlement of 10 million people or more; B: 5 to 10 million; C: 1 to 5 million; D: 500,000 to 1 million and D: 300,000 to 500,000 urban people (source: UN-HABITAT from UNDESA, 2020).

Extending the study to the data given by international organisations [6-8], 141 countries have an urban population rate ≥ 50%, reaching 3,257.16 million of urbanites. This is notorious in countries like China, USA and Brazil.

The expansion of urban population leads to land take and land cover changes, as a support for the development of human activities (housing, industrial or infrastructure construction) [3]. In Europe, from 1990 to 2015, population growth by 2.4% triggered built-up areas by more than 30% [9]. Land taking in EU28, between 2012 and 2018, amounted to 539 km^2/year.

Land take, is a phenomenon that mainly takes place in peri-urban areas [2], areas that are associated with the highest quality soils for agricultural use [8,9] and the proximity food market. From 2000 to 2018 in EU28, more than 78% of occupied land affected agricultural areas, such as arable land and permanent crops (394.34 km^2/year), pastures and mosaic farmland (212.44 km^2/year) [12].

An immediate consequence of cropland decrease is the reduction in potential agricultural production capability to feed a growing population. In fact, Gardi et al. (2015) [3] estimated a loss of more than 6.2 tons of wheat (from 1990 to 2006) due to land take. This is a great concern in developing countries where it is more difficult to find accurate data of land take around the cities. In most of them, the immigration conditioned the increment of suburban areas with low health conditions and insufficient services and resources. This growth is directly associated to land take and soil sealing. Moreover, conditioned by an inexistent land planning and a disorderly occupation of the territory.

Moreover, as population and income levels increase, demand for food rise as well. Between 2000 and 2050, global demand for food crops projected to grow by 70-85% [13]. Meeting rising food needs in terms of both quantity and quality, puts additional pressure on productive capacity of arable fields that last, requires transform forest, semi-natural or natural areas into new agricultural fields, or implies relying on non-local food supply, which could compromise food security [11,14].

It is worth mentioning that loss of arable land is counterbalanced to some extent by increasing in agricultural productivity, but in the long term it will be necessary to use soils from forest or natural areas, which may not be so fertile and be far away [3], and by increasing intensive land management. This can lead to environmental damage [15], which carries an associated impact on a more global scale. Increasing food production through expansion of agriculture, only provides food supply services, but in return, has negative effects on other ecosystem services, such as water availability and quality, carbon sequestration, flood control, ecotourism potential and regulating services [13]. Owing to this, Hardaker et al. (2021) [16] studied the best practices options to enhance ecosystem services provision on arable lands.

In addition, detriment of present and future ecosystem services could be aggravated if soil is sealed. For instance, the percentage of total land take EU28, for green urban areas, between 2012 and 2018, is only 0.52%, the rest allocated to host activities with greater or lesser need to seal or remove the existing fertile soil [12].

Soil sealing defined as “the permanent covering of an area of land and its soil by impermeable artificial material (asphalt or concrete, for instance)”. The average of soil sealed related to population growth, was estimated in 200 m^2 per citizen (by 2006) [11]. Added to consequences previously stated related to land take, soil sealing upsets environmental balance, because soil ecosystem is isolated from others. Impervious soil not only implies a reduction in capacity to provide ecosystem services, but also supposes provision of negative services (disservices) such as intensification of the urban heat island effect, increase risk of flooding, reduce filtering water that drains into aquifers and evapotranspiration, and adversely affect biodiversity and carbon cycle [3,10,16-19]. Consequently, Sobocká et al. (2021) [18] concludes that urban centers are the “most environmentally sensitive area” due to high rates of soil sealing (more than 80%) and urban heat island effects, and lack of green areas.

4. Soil De-sealing and Technosols

In 2020, 2.4% of soil is sealed and only 13% urban development on recycled urban land in Europe. Therefore, the European Union launched the mission “Caring for soil is caring for life”, to ensure 75% of soils are healthy by 2030 for food, people, nature and climate [20], in the same line that many programs from FAO. Among the objectives set, is no net soil sealing and increase to 50% re-use of urban soil, aligned with no net land take by 2050. The net land take concept “combines land take with land return to non-artificial land categories (re-cultivation)”, from urban area to semi-natural land [12]. Accordingly, European Commission proposes direct actions to avoid soil sealing, by reducing land take or by land recycling [15], because land taking mainly for sealing soils without restoring brownfield is unsustainable [10]. Land recycling means “redevelopment of previously developed land (brownfield) for economic purpose, ecological upgrading of land for the purpose of soft-use (green areas in the urban centers) and re-naturalisation of land (bringing it back to nature) by removing existing structures and/or de-sealing surfaces” [21].

Pytel et al. (2021) [22] proposed 8 possible transformation uses of brownfields, such as “cultural, didactic, natural, silvicultural, aquatic, economic, recreational and

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agricultural". In addition, we provide another option for brownfields reused, closely related to provision of ecosystem services, such as construction of wetlands or areas for water purification and run-off regulation [23]. All these new uses can be designed, to a greater or lesser extent, to host green urban areas with adequate ecosystem functionality, and a feasible option to avoid land occupation is to install on preserved constructions, green roofs and green walls. Land recycling for green spaces, can contribute to improve urban green infrastructure, and ecosystem services [10,11]. In fact, urban agriculture can develop on green roofs and walls [24], as well, on urban patches and plots of urban or suburban areas [25]. Nonetheless, in Europe brownfields restoration for green areas is a minority [10], which should be enhanced to compensate ecosystem services loss. Moreover, if reclaimed areas can be used for urban agriculture, it contributes to improvement of human health and food security [26,27].

Furthermore, Lal et al. (2021) [28] consider future land uses for sustainability of cities and megacities and for contributing to the fulfillment of Sustainable Development Goals (SDGs), are those related to urban garden, permaculture, vertical gardening and Technosols. Many cities use urban waste compost for urban agriculture [28], and consider viable incorporation of wastes as a substrate for plant species with agricultural utility [29,30].

Some constraints in the allocation of intended use are size of brownfields (areas between 1 and 20 hectares are suitable for green spaces) [22], soil state (contamination, fertility, among others) [23,31], and previous use mainly related to whether it has been sealed or not. Possibly this is due to the fact that brownfields of heavy industries show high rates of contaminated soils, so to avoid high costs of remediation, they are usually destined for secondary development [18]. Therefore, in the decision of the new use, economic criteria have priority over environmental or social ones [22,32]. Despite the fact that other interests prevail in the decision of the new use of brownfields, the relevance of the environmental benefits is unquestionable. Therefore, authors emphasize the importance of urban agriculture in carbon sequestration. Feliciano et al. (2018) [33], indicates that second largest absolute mean change in soil carbon sequestration reached from the implementation of a home garden on an underutilized land. Carbon sequestration related to agroforestry systems (soil and above ground), depends on "plant species, system characteristics, management factors, agro-ecological conditions and soil characteristics". Among the management factors highlighted by Feliciano et al. (2018) [33], is the use of residues from agroforestry systems [5]. In fact, Lal et al. (2021) [28] indicate that development of agroforestry systems or biochar addition are the only two methods to increase carbon sequestration capacity of soils in the long term.

In other matters, Pytel et al. (2021) [22] provide the most common form of land use in Poland is green spaces, mainly in previous landfills or mine dumps, where there is not an impervious layer. Followed by secondary use mainly associated with post-industrial brownfields. Accordingly, Klenosky et al. (2017) [34] indicate it is common to create green areas on brownfields from landfills. The area occupied by derelict and urban vacant land in Scotland in 2019 is 10,936 hectares, and only 20% of it considered uneconomic to develop or viewed as suitable to reclaim for a 'soft 'use [35]. Consequently, Pytel et al. (2021) [22] consider that new use of recycled land tends to coincide with the use immediately prior to the one that ended up in disuse, as its reconversion is cheaper and easier. Still, in Scotland in 2019, 405 hectares of 10,936 urban vacant hectares previously used for agricultural purposes, and only 13 hectares brought back into agriculture use [35]. For urban agriculture, in addition to soil contamination factor [26,27], soil fertility is limiting. The development project of a children's museum, for the improvement of nutritional habits and production of food in gardens, needed fertile soil and organic compost to replace poor topsoil [36].

Sobocká et al. (2021) [18] consider brownfields that have hosted highly polluting activities should not be reclaimed for residential development or housing the most sensitive population, nor for green parks, without proceeding to cover contaminated soil with a layer of topsoil (at least 50 cm). As indicate by Pecina et al. (2021) [31], for agricultural use it would also be advisable to be cautious [37]. As healthy soils generate healthy crops, which is crucial to human health and agricultural productivity [28]. Moreover, Deeb et al. (2020) [37] contemplate that constructed Technosols show great potential for brownfields restoration. De Sousa (2017) [32] indicates among remediation techniques for transformation of brownfields, the predominant is excavation, soil removal and backfill.

Therefore, at times, previous steep to green land recycling is de-sealing soil. Which implies, according to the European Commission, "Removing asphalt or concrete and replacing them with topsoil on subsoil" [15]. At this point, we wonder if it is necessary to use topsoil from elsewhere to restore de-sealed soils, if de-sealed soils can achieve ecosystem services levels prior to sealing, and if so, if de-sealed soils can become biomass producers. Sealed soils experience an alteration of their properties, worse soil structure and organic matter, and moderate to high amount of trace elements, leading to a drastic reduction in microbial community, among others aftermaths [17,18]. In cases where it is completely necessary to add topsoil on de-sealed soils, an option to consider may be incorporation of Technosols made by wastes, to enhance ecosystem services [38]. It could be a new line of research, as authors have not found references in this context. Authors consider sealed soil is not a reversible process [39]. Maybe this needs more discussion, depending on removing impervious layer or not. In fact, Tobias et al. (2018) [10] consider all de-sealed brownfields have potential for providing ecosystem services if soil is restored. Recent references conclude de-sealed soils can restore their quality and fertility, by themselves, without adding topsoil [40]. De-sealed soils can even improve functional and biological levels, with shrub planting and irrigation.

As indicated by the aforementioned references, de-sealed soils can recover their ecosystem functions. However, would it also include the provision of food? Authors aim to discern if it is a feasible option to balance the loss of fertile soil for agricultural use, with de-sealed urban soil. The conclusions of Tobias et al. (2018) [10], establish sealed soils with agricultural potential can reclaimed for food production, although at times the degree of soil compaction may be limiting. In addition, it would be convenient to know if de-sealed soils may need additional treatments and on what timescale, to become suitable for agricultural re-use. This paper [41], addressed this question, concluding de-sealed soils, without any additional treatment, only allowing colonization of spontaneous vegetation, improve their physical and chemical fertility. Even more, this can increase microbial biomass and biochemical activity, exceeding the values of agricultural soils.

Research is needed in this sense, because there were scarce references related to brownfield reclamation (sealed or not) for urban agriculture and using made by waste Technosols for improving soil properties and functions. Technosols and the use of wastes can be a solution, mostly of them that can be considered as bioresources coming for many activities (i.e., food waste) [42].

5. Conclusions

In 2020, the countries with more than half of their population in urban environments cover most of the habitable terrestrial territory. The expected increase in population will be associated with a rise in the number and size of cities worldwide (in Europe, the cities that will increase the most will be those with 500,000 to 1 million and those with 300,000 to 500,000 inhabitants), as well, with land take mainly affecting fertile soils. Consequently, it will be a challenge for food supply, food security and to provide ecosystem services.

Furthermore, most of the soil affected by land take is sealed, which implies provision of ecosystem disservices. To counteract it, the European Union, in addition to limiting land take, is promoting land recycling. Land recycling for green areas can enhance ecosystem services, an adding Technosols made by wastes, increase sustainability of cities and megacities, improve agricultural productivity and human health. Consequently, brownfield regeneration may go beyond constructing of new facilities that have an aesthetic, productive or recreational use, with the implementation of green areas.

At the same time, it would be advisable to avoid using natural soil to fill, bioremediate, or improve soil properties for urban agriculture, since the incorporation of Technosols as a substrate for crops, support of green areas and forest urban areas is a viable option. Besides, using de-sealed soils after rehabilitation for agricultural production seems to be a real possibility.

More information on land rehabilitation, Technosols and de-sealed soils for urban arable land uses would help us to establish a greater degree of accuracy on this matter. So, new research and data supporting urban soil rehabilitation should be a target for local, regional and national administrations in order to improve our health and urban environments.

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