Catena 149 (2017) 341–348

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Sustainable use of sewage sludge in acid soils within a circular economy perspective

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ARTICLE INFO

Article history:
Received 10 May 2016
Received in revised form 9 September 2016
Accepted 10 October 2016
Available online xxxx

Keywords:
Nickel
Chromium
Copper
Mercury
Zinc
Lead

ABSTRACT

Fertiliser future shortage and the associated increased economic and environment transport costs are key reasons to promote the use of urban residues as fertilisers in agriculture. Sewage sludge (SS) use as a fertiliser is promoted by the EU, which also consider the harmful effects of heavy metals (HMs). It is important to characterise the levels of HM in soils allocated to pasture and forage crops, before SS application, in order to have an initial soil reference and to see how they vary over time specially in acid soils, where HM availability and therefore its ecosystem impact is larger. For this study, we selected a region with natural very acid soils, and with high needs of fertilisers due to the high crop production potential regarding to important crops like maize, forage crops and grasslands. Galicia is a small region of Spain (9% of the Spanish territory) that produces the 33% and the 60% of the woodland products of Spain. This study generally aims to evaluate the use of SS as a fertiliser in a large agronomic region of Spain, as well as to identify the disadvantages associated with its use. In concrete terms, the study aims at comparing the implications of the current limit values and the analysis of the implications of tighter limits imposed by the EC to evaluate the effect on the availability of sites for sludge applications in Galicia. Results indicate that, after the analysis of 2557 soils, more than the 90% of Galician soils are suitable to receive sewage sludge (SS) following the current regulation RD 1310/90 but only 28.7% fulfil the EUDWD (European Union Draft Working Document) requirements. Most of the samples that do not fulfil the Spanish regulation are associated with basic and ultrabasic rocks that define natural environments with specific plants and soil microorganisms already adapted to these levels of HM. In order to apply more sustainable practices for agricultural production, it is proposed to take into account the mean HM levels of the soil for each heavy metal (HM) trying not to surpass the mean levels of the soils derived from the different parent rock material, after considering human health risks. Moreover, this recommendation would respect the original environment of the soil that acts as a habitat for different organisms, preserving beta biodiversity.

1. Introduction

Soil sustainable use and health is one of the key aspects to maintain and promote sustainable agriculture production. Fertilization is one of the most spread management activity linked to agriculture. However, due to the economic and environment costs of the fertiliser transport, fertilization based on farm surrounding residues is promoted within the FAO mixed farming concept (FAO, 2015). Urban-agriculture exchange of energy and nutrients should be promoted through activities (i.e. kilometer zero) like the use of urban residues in agricultural lands.

The bioeconomy concept relies on addressing inter-connected societal challenges such as food security, natural resource scarcity, fossil resource dependence and climate change, while achieving sustainable economic growth. The bioeconomy concept provides a useful basis for such approach, as it encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy (EC, 2012). It is essential to add-value to waste products, of which SS is one of the most important ones due to the large amounts of production of this residue in Europe as already recognized the FAO Smart Climate Agriculture document (FAO, 2013).

High levels of contamination in continental waters caused by humans promoted the establishment of the waste water directive in the nineties in Europe. Waste water is being also used as a source of nutrients in many countries (Ghafoor et al., 2012). The production of municipal SS in Europe has been increased since the start of the 1990s of the last century due to the implementation of the 91/271/CEE Directive,

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http://dx.doi.org/10.1016/j.catena.2016.10.007

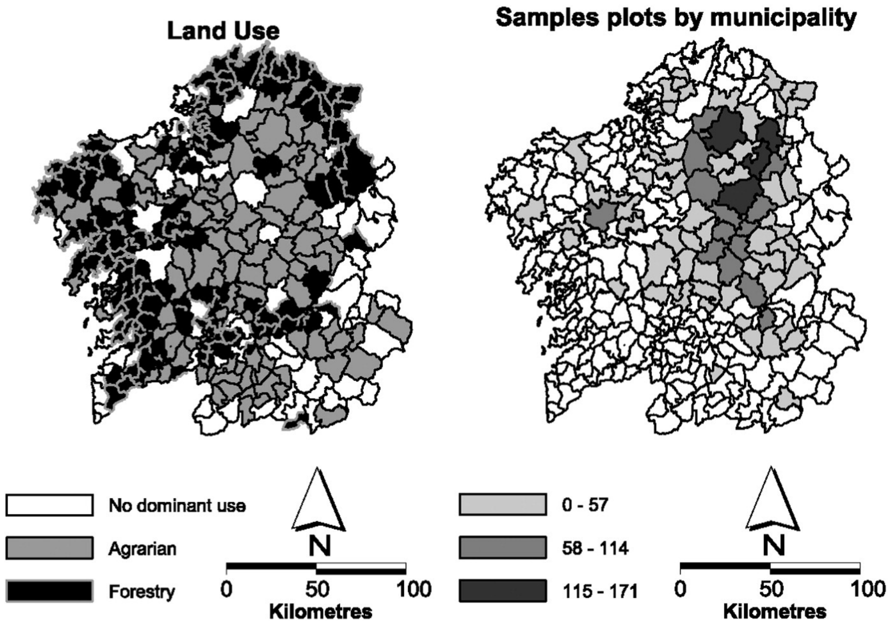

Fig. 1. Galician dominant land use (left) and number of soils sampled by county (right) in the current experiment.

which makes compulsory to treat continental waters in all cities with >2000 inhabitants. So, the availability of this residue is ensured and usually perceived as a challenge due to the high level of nutrients that can provide to crops.

Sewage sludge elimination could be done by transport to landfill, by incineration, which causes nitrogen release into the atmosphere (Smith, 1996; EPA, 2012) or by using it in soils. The use of SS as a fertiliser in soils is promoted by the European Union due to its nutrient contents, mainly nitrogen but also phosphorus, which could increase the value of this residue that otherwise, would generate environmental problems (Smith, 1996; 91/271/CEE Directive). This practice is also in line with the bioeconomy and circular economy concepts, providing an added value to the residue. One of the main concerns of SS use in soils as a fertiliser is related to the higher levels of HM and other organic substances compared with soils, which could be absorbed by plants and affect human beings through the food chain (Roy and McDonald, in press). Moreover,

Table 1
Statistical summary of selected properties for 2597 Galician soil samples used in this study compared with current and draft regulations. Min: minimum value, Max: maximum value; SD: standard deviation; notice that there were 1558 samples (41%) out of 2597 with pH below 5. Values between brackets represent the percentage of all samples for each directive.

Property	Value						
	Min–Max	Mean	SD	Median	Skewness	Kurtosis	90 percentile
pH-H_2O	3.44–10.22	5.21	0.72	5.17	1.25	5.67	6.05
Cd (mg kg^{-1})	0.01–2.50	0.05	0.15	0.01	5.63	50.07	0.10
Ni (mg kg^{-1})	0.001–169.50	12.20	14.28	8.90	2.31	10.80	27.70
Pb (mg kg^{-1})	0.01–118.50	10.21	12.13	6.60	1.75	5.34	27.12
Zn (mg kg^{-1})	0.01–306.70	45.33	30.46	41.20	1.58	6.39	81.92
Hg (mg kg^{-1})	0.01–0.80	0.054	0.05	0.05	5.33	52.08	0.10
Cr (mg kg^{-1})	0.01–236.94	10.03	16.54	5.80	4.87	37.09	22.32
Cu (mg kg^{-1})	0.01–212.00	16.38	17.98	12.30	3.73	23.98	34.70

Property	Value														
	Legal requirements for use sewage sludge in soils. Samples below/above the limits														
	RD 1310/1990 (*Directive 91/271/EEC*)						3rd Draft Working Document on sludge (EU)								
	pH ≤ 7	n = 2559		pH > 7	n = 38		5 ≤ pH < 6	n = 1230		6 ≤ pH < 7	n = 263		pH > 7	n = 38	
	Limit	Below	Over	Limit	Below	Over	Limit	Below	Over	Limit	Below	Over	Limit	Below	Over
Cd (mg kg^{-1})	1	2557 (98.4)	2 (0.1)	3	38 (1.5)	0 (0)	0.5	1203 (46.3)	27 (1.0)	1	262 (10.1)	1 (0)	1.5	38 (1.5)	0 (0)
Ni (mg kg^{-1})	30	2408 (92.7)	151 (5.8)	112	38 (1.5)	0 (0)	15	770 (29.6)	460 (17.7)	50	261 (10.1)	2 (0.1)	70	36 (1.4)	2 (0.1)
Pb (mg kg^{-1})	50	2548 (98.1)	11 (0.4)	300	38 (1.5)	0 (0)	70	1230 (47.4)	0 (0)	70	263 (10.1)	0 (0)	100	38 (1.5)	0 (0)
Zn (mg kg^{-1})	150	2540 (97.8)	19 (0.7)	450	38 (1.5)	0 (0)	60	880 (33.9)	350 (13.5)	150	262 (10.1)	1 (0)	200	37 (1.4)	1 (0)
Hg (mg kg^{-1})	1	2559 (98.5)	0 (0)	1.5	38 (1.5)	0 (0)	0.1	1090 (42.0)	140 (5.4)	0.5	263 (10.1)	0 (0)	1	38 (1.5)	0 (0)
Cr (mg kg^{-1})	100	2550 (98.1)	9 (0.3)	150	38 (1.5)	0 (0)	30	1111 (42.8)	119 (4.6)	60	263 (10.1)	4 (0.2)	100	38 (1.5)	0 (0)
Cu (mg kg^{-1})	50	2504 (96.4)	55 (2.1)	210	38 (1.5)	0 (0)	20	837 (32.2)	393 (15.1)	50	263 (10.1)	0 (0)	100	38 (1.5)	0 (0)