Site selection of centralized facilities for animal manure treatment

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Abstract
The optimal location of centralized treatment plants of animal manures should consider both the environmental and urban regulations, and the transportation costs of raw manure to the plant and of treated manures back to the farms or the land where they can be spread. With the aim to consider these different aspects in a comprehensive approach, a methodology has been developed to identify the best possible locations of a centralized treatment plant in a defined area. The methodology developed, implemented in a simulation model, is based on the transport distance of manure and a ranking of the suitability of possible sites based on a multicriteria analysis (MCA). The methodology has been applied to an intensive livestock area where different management scenarios and treatment systems has been compared. The results obtained confirm the potential use of the defined methodology.

Introduction
In an area with high density of livestock and high nitrogen loads the risk of pollution of the air, water and soil quality increases. Of particular importance are the emissions of nitrous oxide (N_2O), methane (CH_4) and ammonia (NH_3) in the atmosphere and nitrate (NO_3) and phosphorus to the surface waters and groundwater. They contribute to global warming, acidification, eutrophication and increasing nitrates in water [1]. The environmental impact is greatly aggravated by the imbalance between the growing demand for animal production and the shortage of available land for manure utilization. Manure treatment can be a suitable solution to reduce the risk of pollution, contributing to crop fertilization and reducing the use of mineral fertilizers. To get these results it is often necessary to achieve treatment facilities for livestock manure that are not adequate for individual farms. The optimal location of centralized treatment plants of animal manures should consider both the environmental and urban regulations [2], and the transportation costs of raw manure to the plant and of treated manures back to the farms or to the land where they can be spread. The purpose of this paper is to present a methodology to identify the best locations of a centralized treatment plant and to discuss its application in a livestock area in Northern Italy.

Material and Methods
To identify the suitable sites for centralized manure treatment facilities location two main elements have been considered. The first concerns the opportunity to identify, among the areas available for the construction of a plant, those that are better from the environmental aspects. This requires care of the characteristics of the surrounding area and the impact that comes from the realization of the work planned. The second factor concerns the choice of a location that optimizes the transport of the effluents from the individual livestock farms to the treatment plant. These two elements must be analysed together and should lead to a harmonised assessment of the different elements analysed in order to provide a direct response to the suitability of the territory as site for the treatment site.
It is necessary to consider the position of the farms in the area, the quantities of liquid manure and fields available for distribution, in order to assess the effect of changes on the production system and ensure its sustainability according to law provisions. For this purpose, a methodology has been developed to support the position of a centralized manure treatment according to the farms involved (location and amount of manure produced) and applied to a high density livestock area in the Lodi Province, south of Milan, Italy. The methodology has been applied to a territory that includes 53 farms distributed on six municipalities. A numeric and cartographic database of the farms containing detailed information of the livestock and of the fields was available.
The methodological model implemented (Figure 1), provides the determination of the suitability of each territorial units. We identified the cadastral parcels (CD) as reference unit in order to have maps of the farm land suitable for manure spreading or for the building of the centralized plant.

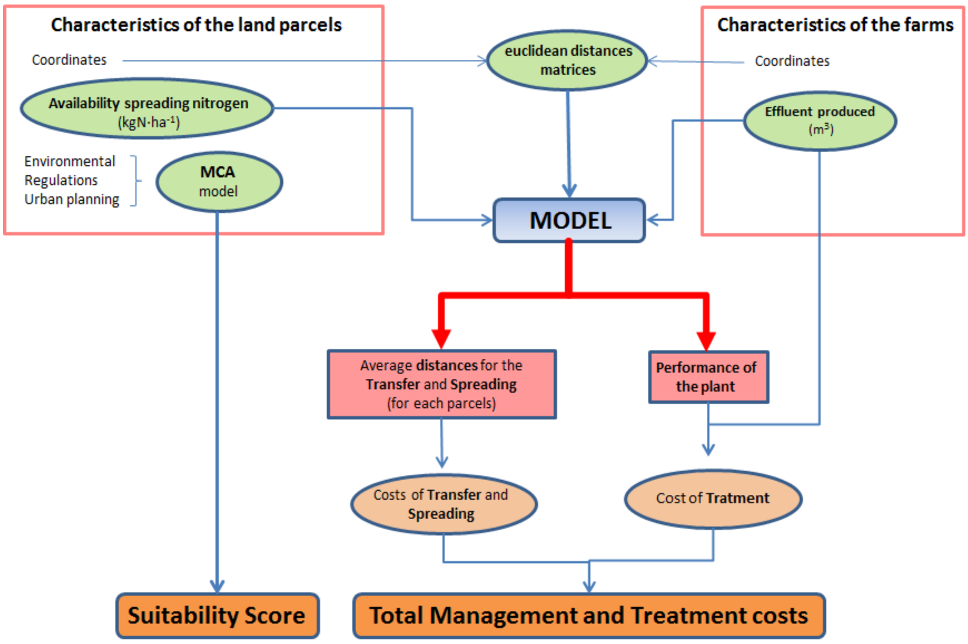

Figure 1. Methodological framework for the calculation of treatment and management costs.

The method uses an MCA to identify the most suitable areas to locate the centralized treatment plant. To identify suitable CDs, the specific areas of the territory in which, for environmental, legislation and urban planning constraints where it is impossible to build this type of plant should be discarded. The method considers distances from existing infrastructure, distance from water bodies, areas with urban or environmental issues and natural morphology of the territory. Such information, based on existing indications [2][3][4], were used to determine the most suitable areas to locate the plant. Through the MCA has been analysed every CDs and they have been classified numerically using a number of criteria in order to obtain a land classification. So, a value has been assigned to each CD in a range between 0 and 100, where 100 is the worst score and 0 is the best. A further evaluation has been carried out to consider the logistics and economics issues to define the possible site of the plant. The suitability, in this case, depends both from the distance between farms and facilities, for the transport of the livestock manure produced, and from the distance between the facilities and the fields used for spreading the treated manure. For this purpose, the matrix of the Euclidean distances (km) between farms and CDs and the amount of distributable nitrogen on each CD have been calculated. The linear distances matrix has been built using the coordinates of the CD and farms. Instead the maximum amount of nitrogen applicable, established by legislation, was calculated. If the amount of nitrogen produced by farms was greater than the amount of nitrogen distributable on the CD, a biological nitrogen removal system is introduced in the centralized treatment facility. Two different manure treatment systems were foreseen with different efficiencies. The first (NDN) is a nitrification-denitrification process with high nitrogen removal (80%) while the second allows a more limited nitrogen removal (60%) and is a sequential batch reactor (SBR).

Figure 2 shows one of the logical schemes of the scenario considered in this work where all the farms manure are transported to the centralised plant. Other manure management schemes have been analyzed but not reported here.

According to the distance matrix, the effluent volume to be treated and its nitrogen content, before and after treatment, a model has been implemented that calculates the average distances of conferring the manure product and the application of treated manure to the land. This distance has been transformed into the transfer and redistribution cost of the effluent based on previous works [1],[5]. Through minimizing these costs has been possible to identify which CD are the best candidates to siting the plant from a logistic point of view.

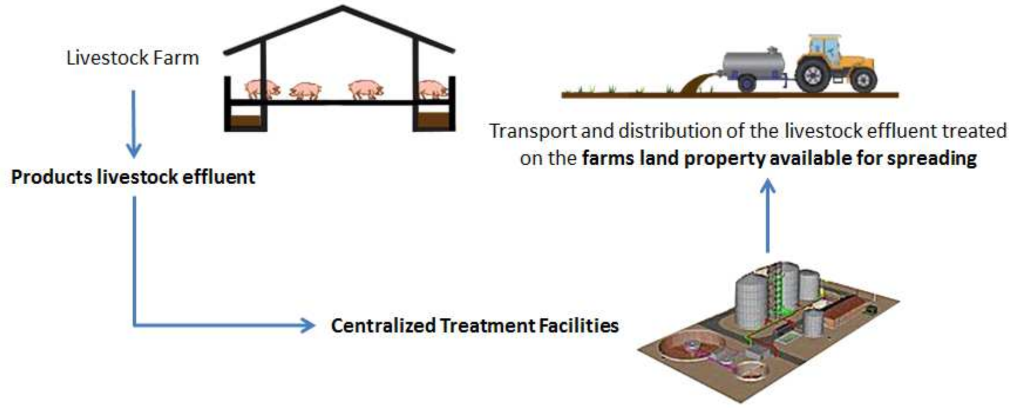

Figure 2. The farms confer all livestock effluents products to the treatment facility that provides to redistribute on the farm land property once treated.

We have defined an indicator for the classification of the suitable CD by combining the management cost of the manure with the suitability score obtained by MCA. The result is an indicator that classify the CD suitability for the plant. The worst CDs have been classified with a score over 100 points and the best CDs have been classified with a score between 60 and 70 points.

Results

An example of the application of the methodology have been reported here and refers to a group of 11 farms located in the northern part of the study area.

Figure 3 shows the CDs best candidate (dark blue) for location of the plan and classified according to the indicator of choice particle that allows to rate and considering together the total cost (management and treatment) and the suitability scores attributed to each particle. The map on the right use more restrictive criteria for plant location in term of distances from rivers and building and therefore increases the CDs not suitable.

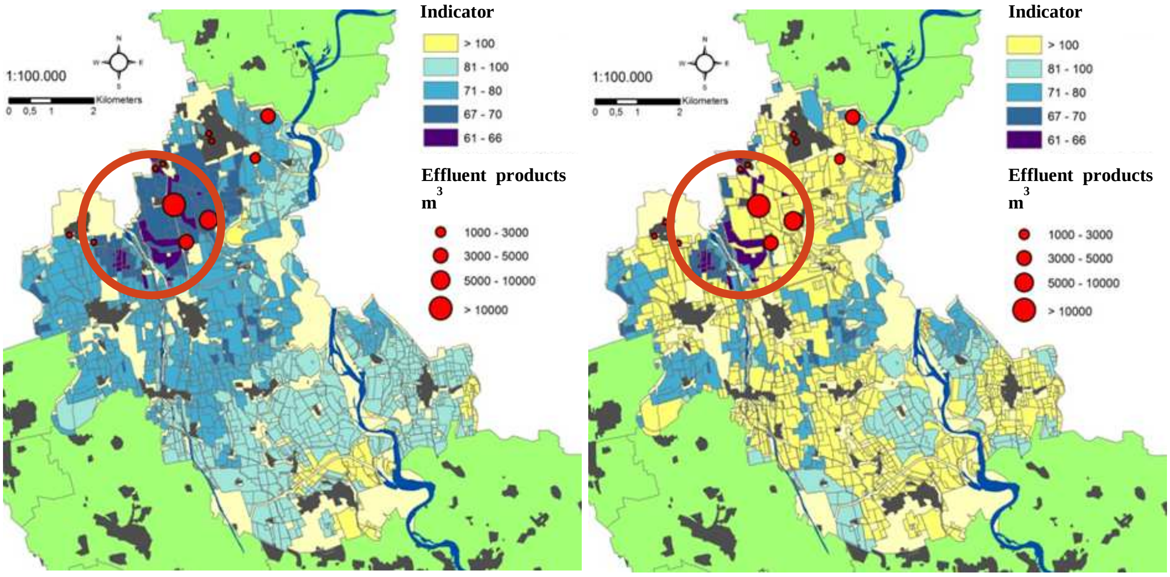

Figure 3. Map of the indicator for the location of the plant applied to a group of farms (orange circles), on the left the situation with all potentially suitable land, on the right, with limitation for distances to rives and other buildings.

Figure 4 has reports the management and treatment cost calculated for the best CD potentially available for the construction of the plant. The cost refers to the two technologies considered and for two possible clustering of farms: the first considers a single treatment plant for the whole area while the second provides the possibility of realizing three plants serving the farms in three zones of the area.

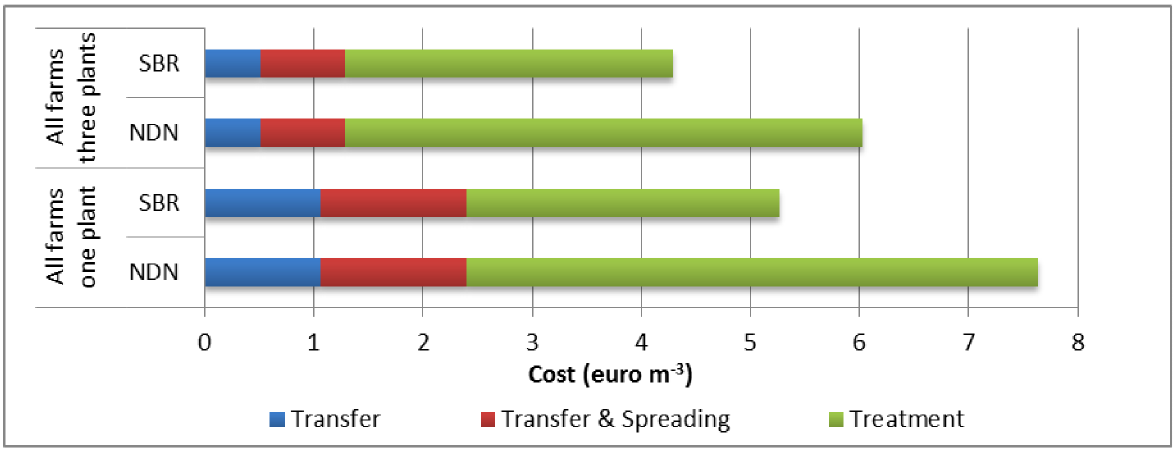

Figure 4. Management cost and effluent treatment.

The manure management costs of the various systems and different treatment strategies analysed were evaluated between 4.80 and 7.60 € m^{-3} of manure. Figure 4 shows also how treatment cost significantly affects the total cost, with an incidence always higher than 3 € m^{-3}. The possible location of the plant is strongly conditioned by territorial constraints imposed. The plants serving a smaller number of farms have a higher investment cost of the treatment plants but, due to the reduced distance of transport, lower the overall costs of 17-18% depending on the manure management scheme and the type of treatment used.

Conclusion and perspectives

It has been proposed a method of site selection based on MCA for identifying the best areas for the location of a collective plant for manure management and nitrogen removal. This tool can be a useful support to the assessment, but it should be given considerable attention to the selection and weight of the criteria for analysis. These parameters can be very different depending on the territory features considered. Although with some limitations due to the availability of spatial data, the defined method has provided interesting results and immediate operational application. The definition of decision support systems based on these methods can support the definition of optimal solutions, taking into account environmental issues and management costs. It will also support farmers in making their business sustainable in accordance of legal provisions.

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