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Short communication

Organic wastes management in a circular economy approach: Rebuilding the link between urban and rural areas

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ABSTRACT

The food chain has produced a break of carbon and nutrient cycles causing problems in local and global environment. It induces a growing use of chemical fertilizers, irrigation needs, energy use and greenhouse gases emissions. It also reduces the resilience of soils to climate change. This paper describes a technological process to restore the broken cycle of organic matter. The process is based on an anaerobic digestion followed by a composting enriched with earthworms, to produce bio-methane and humus in an optimised chain. Multiple are the environmental benefits: to produce a fuel with carbon dioxide emissions balanced, to enrich soils reducing the need of irrigation and the need of chemical fertilizers. Meanwhile the humus produced increases the carbon stock of soils and improve the carbon fixed by photosynthesis, closing the carbon cycle.

The comparison of data of humus produced by composting and the "combined anaerobic digestion and composting" proposed are quite similar. Therefore the added value of the process described is the production of a renewable methane and avoiding its dispersion in the atmosphere; we remember that methane has a $GWP_{20} = 56$. Adding earthworms in the composting treatment enrichs compost with hormones which increase the growth of plants, reducing the fertilising needs. It implies a reduction of Nitrous Oxide (N_2O) produced by denitrifying bacteria that has a $GWP_{100} = 265$ (IPCC, 2013).

1. Introduction

1.1. A world of circular systems

In a systemic description, living forms are characterized by a steady organizational scheme, even if in a progressive evolution, and by a structure undergoing change through a continuous flow of energy and matter (Masullo, 2008; Masullo, 2014; Sertorio and Renda, 2009). These living structures are open systems linked by ecological nets where the wastes of one are nourishment for the others. In the ecological nets, plants have an important role in connecting living with not-living systems. Plants use solar energy and absorb water and minerals from the ground and CO_2 from the atmosphere, creating sugars, proteins and other organic compounds. They are the real factories of the bricks of life, being the connection between living and not-living organised systems. The flow of nutrients that crosses an ecosystem is not always regular and consistent, but it often implies cyclic movements of matter and energy among its parts. A typical example is the carbon cycle whose huge tanks, atmosphere, oceans, carbonate rocks and biomass pulse as big synchronized pumps, feeding the flow of carbon like the heart in a circulatory system.

Among the several evolutionary pathways that a living system can cover in its history, the one able to keep inside the most quantity of energy and matter made available by the ecosystem, which it belongs to, always prevails transforming it in organization. An evolution from disorder towards order involves in a coordinated way all the living systems belonging to a certain ecosystem. This process tends to the maximum efficiency in the exploitation of available resources. No species prevail until the point of causing the extinction of the others but there is a cooperative competition oriented to the maximum efficiency; the bigger is the biological complexity of the ecosystem, namely its biodiversity, the bigger is its ability to capture and use the energy that crosses it. The dying out of a species happens when because of the external conditions changing, other species can take more efficiently the "space" it had in the ecosystem to which it belongs, we are talking not about the physical space, but about the functional space (use of available resources and supply of matter and energy to other species).

If we extend such remarks to the whole planet, we can see that the world tends spontaneously to annihilate all differences and consequently to exhaust all the possible transformations, doing it generating flows of energy and matter. Living systems are part of that class of dissipative systems that, if crossed by a continuous flow

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of energy and matter, use it to go far-from equilibrium creating and keeping differences with the outside environment. For a living system to be far from equilibrium means that it has stored a certain quantity of usable energy (low entropy), in the form of biochemical energy. The difference of concentration of the several elements that form the living system structure compared to the outside environment macroscopically underline this situation. This difference gives the possibility to identify it as a distinct unit from the surrounding context, that we can consider as a situation of dispersion to which the system tends when the flow of energy ends, and it dies. In warm-blooded animals, the difference of the constant body temperature and that variable of the outside environment reveals more clearly this energetic difference (Margulis and Sagan, 1987).

The energy that moves the living systems is solar energy that enters directly, or through the biomasses produced by its action, along the food chain. Solar energy acts directly through photosynthesis in the production of phytoplankton and plant biomass. It is partially stored in the system's structure through a process of concentration of basic elements like oxygen, hydrogen, carbon, nitrogen, etc. into organic molecules that form the living system. Through this process solar radiation is transformed and stored as biochemical energy. The energy is partially stored in the system organization where the organic molecules interact, transforming the biochemical energy in movement (work produced by the muscular contraction) or producing heat, or also resolving and forming molecules through the metabolic reactions (food digestion) for the system maintenance and growth. We are talking about system and not organism, because we can apply these remarks to the single organism and to the whole of the organisms that interact in an ecosystem, as to the whole biosphere.

In summary, a living system receives the flow of energy and matter from the surrounding environment. It partially keeps this energy in its structure as biochemical energy and partially disperses it as heat directly or through the expulsion of matter outside the system.

In the annual balance of an ecosystem in a stationary situation, namely a situation wherein the quantity of energy and matter that enters the system is the same that goes out, the quantity of solar energy captured is determined by the system structure (e.g. by the energy stored and biomass produced). Therefore, if the input of energy and matter increases because of the structural growth, the energy dispersed will also increase. Furthermore, a bigger structure needs a higher quantity of energy and matter for its maintenance. A wider circulation of energy and matter inside the system before exiting, allows its more efficient use, producing more biomass without increasing the inputs. The energy and material flow through an ecosystem implies a direct effect, which is a growth in biomass, and an indirect effect caused by the circulation of material and energy into the system that implies an improvement of biomass without the growth of the input; this means a more efficient use of the available energy. Thus, living systems tend to increase their capability of storing energy, to increase their distance from equilibrium with the outside environment, in other words, to increase the differences. They mainly do it in two ways:

- Growth of the physical dimensions and, consequently, of the flow of solar energy captured. This allows a higher capture of the incident solar radiation but it also implies a higher energy for maintenance. The ecosystem biomass, that is to say its physical structure, grows.
- Growth of the ecosystem network, thereby achieving a longer circulation of energy and matter, improving its organizational complexity so that the solar energy and materials received can circulate for a longer time inside it.

Table 1
Exergy utilisation and the exergy storage (Jorgensen, 1998).

Ecosystem	Exergy storage kJ/m^2	% Exergy utilisation
Quarry	0	6
Desert	73	2
Clear Cut	594	49
Grassland	940	59
Fir Plantation	12700	70
Natural Forest	26000	71
Old deciduous forest	38000	72
Tropical rainforests	64000	70

This means an increase of genetic information and thus of complexity. The system (organism or ecosystem) tends to become more efficient and normally carries more information (an organism with a more complex genetic code). Biodiversity increases, and the number and specialization of ecological niches, increases. The overall information, namely the genetic and biochemical complexity, increases (Jorgensen and Fath, 2002; Jorgensen, 1998).

Therefore, the economy of nature is a circular economy. It proceeds by linking cyclic processes that release matter and energy in the same conditions and at the same point of the cycle from where it took them, after remaining in a state of utility; this allows it to proceed without limits on its road of creation of complexity and efficiency. In a circular economy, the effect is to not only transfer matter from one place and accumulate it somewhere else. The objective is to circulate matter to create organization and improve organised systems by increasing quality. Everything moves in this direction. (Kauffman, 2008)

1.2. *Exergy: the added value in a circular economy*

The "usable energy" stored in living systems is called exergy. The existence of human civilisation is possible thanks to the use of natural resources. In economy, natural resources are all that materials being in a chemical and physical state different from the state they are in the surrounding environment; this makes them susceptible to transformations. The standard values of the state parameters, are commonly considered as the zero level of utility so for a natural resource as for industrial products. Exergy is the possibility, for a system far from standard conditions, to perform a work.

Exergy is the work that a system can perform moving from its state to achieve the thermodynamic equilibrium with the surrounding environment. The exergy of an object is the minimum energy needed for its production starting from the concentration of its components in the surrounding environment, by a reversible process and using the environment as the only energy source. We can measure a loss of exergy every time a work is performed or some materials, structured into a system, are dispersed as wastes. In other words, exergy is the energy ready to be available in a particular system being in a particular place, due to the distance between the thermodynamic state of the system and the surrounding environment. Therefore, exergy is a function that represent a link between thermodynamics and economy and can be used to evaluate the environmental costs of any transformation process.

Table. 1 shows the exergy utilisation as percentage of solar radiation for different types of ecosystems, listed by complexity, and the exergy storage. If we consider such a list as an evolutionary pattern, we can affirm that when a system is in an initial stage of evolution, meaning low complexity and low biodiversity, there is a linear relationship between exergy capture and exergy storage; in a mature system the exergy capture reach a maximum, while the exergy storage continues to grow.

1 Therefore we can deduce that an eco-system has three ways to grow:Growth of the physical structure (biomass)