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Syntropy and innovation in agriculture

Dayana Andrade[1], Felipe Pasini[1] and Fabio Rubio Scarano[1,2]

Agriculture is one of the main examples of the interface humankind-nature-technology. However, innovation in agriculture has often been associated to only one component of this tryptic: technology – in particular its development, use and application. In this paper, we argue that the innovation space in agriculture is migrating from an emphasis in technology, aiming to achieve economic goals related to productivity, to an emphasis on the relationship humankind-nature, aiming for a greater balance between social, economic and environmental goals. This shift is gaining traction in the 21st Century, largely in response to the limits imposed by the Anthropocene. Therefore, many of the various branches of agroecology emerge as important innovations. We examine one in particular, the syntropic agriculture, as a case study of an innovative approach to sustainable farming. We argue that syntropic agriculture is scalable and has had an increasing adoption in Brazil and many other countries. It successfully achieves productivity targets, while promoting succession and regeneration of native ecosystems. This pattern results from the combination of a rationale that blends scientific and traditional knowledge, a practice that resorts to no-impact or low-impact technologies, and a philosophy that perceives humankind and nature as integrated and interdependent.

Addresses
[1] Universidade Federal do Rio de Janeiro, Programa de Pós-Graduação em Ciências Ambientais e Conservação, Macaé, RJ, Brazil
[2] Universidade Federal do Rio de Janeiro, Departamento de Ecologia, Rio de Janeiro, RJ, Brazil

Corresponding author: Scarano, Fabio Rubio (fscarano@gmail.com)

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Introduction

Agriculture (croplands and pastures) is one of the most predominant land use forms, and covers some 4.9 billion hectares, or 38% of Earth's terrestrial surface [1]. Its expansion has affected the entire biosphere and has been one of the key drivers of the series of physical, chemical and biological events that led the planet to entering the Anthropocene – the era in which human activities impact the natural systems that support life on Earth to the extent of driving them to a disruptive limit [2–4]. For instance, agriculture has been associated to decline of species and ecosystems [5], to up to 10% of global greenhouse gas emissions [6], to a large water footprint (responsible for 70% of global freshwater withdrawals) [7], and to land, water, and air pollution by disrupting global nitrogen and phosphorus cycles [8]. Moreover, many agricultural systems have low resilience to changes in climate [9], and, at least in the global south, they have caused intense social conflicts [10]. Still, agriculture remains essential for global food security [1]. Perhaps because of these outcomes and also its scale, agriculture remains as one of the most outstanding examples of the challenges resulting from the interaction between humankind and nature through technology. Across the centuries, innovation in agriculture has been mostly associated to technology, aiming to achieve economic goals related to productivity. Since sustainability emerged as an antidote to the Anthropocene, our argument in this paper is that the innovation space in agriculture is migrating from an emphasis in technology, to an emphasis on the relationship humankind-nature, aiming for a greater balance between social, economic and environmental goals. In this context, we use syntropic agriculture, a particular type of agroecological practice, as case study.

Innovation across history

Innovation may occur at product or at process level [11]. In the case of agriculture, innovation then takes place at the production front or at the organisation of the ag-food systems. From Antiquity to Medieval agriculture, organisation shifted from nomadic to sedentary to a system of exchange. In parallel, new production practices emerged, ranging from slash-and-burn, plowing, irrigation through to rotation and fallow. In Modern Age there has been a higher intensity of innovation at the organisation front. Economic growth, commerce and markets provoked changes in the production system. Industrialisation and specialisation changed priorities for production and the concept of property interfered directly in the production management. For the past 200 years, innovation at both production and organisation fronts speeded up largely due to science and technology (e.g. high-yielding varieties, pesticides, fertilisers, mechanisation and infrastructure) and resulted on gigantic increases in yield. On the other hand, it is precisely this extensive innovation that is largely related to the onset of the Anthropocene [2]. Interestingly, from 2010 to 2017, the Food and Agriculture Organisation (FAO) placed a lot of emphasis on climate-smart agriculture [12], sustainable crop production intensification [13], and conservation agriculture [14] – all of which aim at higher sustainability on agriculture with innovations that remain technology driven. It is only more recently that the FAO [15•] highlighted the role of agroecology in helping shift agri-food systems to a healthier and more sustainable path. Still, by some [16••] this was interpreted as agroecology being treated as one more tool in the toolbox of industrial agriculture.

Although agroecology emerges as practice but also as science [17••], its innovation component, we argue, is related more to the relationship humankind-nature than to the technology component (Table 1). Evidence for that can both be perceived on the scientific front, which is both interdisciplinary and transdisciplinary (including Agronomics, but also Ecology, Economics, Sociology; and non-academic actors) [18,19], and on the actual practice at the field. For instance, it is often claimed that agroecology has boosted the dialogue between conventional and traditional knowledge, and has incorporated social (e.g. gender and racial equality, food sovereignty) and environmental (e.g. conservation of agrobiodiversity, combat to pesticides) movement agendas [20,21].

Syntropic agriculture as a particular type of innovation in agroecology

There is a myriad of terms that refer to practices and systems that arguably belong to the domain of agroecology: agroforestry, biological agriculture, holistic agriculture, natural agriculture, organic agriculture, permaculture, regenerative agriculture, among others. However, agroecology as a whole can be broadly divided in two camps: agroecology that 'conforms' (i.e. can be adaptable to industrial, technological agricultural as one additional tool) and agroecology that 'transforms' (i.e. changes food systems and territories based on a balanced human-nature perspective) [14]. While the former may circumvent scalability issues often related to agroecology [22], the latter is not adaptable to high-tech agriculture and may face challenges related to production volume (but see Table 2). Syntropic agriculture (developed over 45 years by Swiss farmer Ernst Götsch, who lives in Brazil since 1982) fits the category of agriculture that transforms, and is therefore faced by scalability issues as we discuss later.

Table 1

Agroecological approaches and foci, according to multiple authors [16••,17••,32–36]

Agroecological focus	Approach
Ecosystemic	Compares natural world and agroecosystems
Ecological	Use of population ecology theories
Political	Emphasis on aspects related to policy and socioeconomics
Agronomic	Search for sustainability in the agricultural system
Landscape	Emphasis on multifunctionality of territories
Indigenous and traditional	Dialogue and incorporation of traditional cultivation systems

Nevertheless, syntropic agriculture is spreading out. In 1993, it began to spread among Brazilian farmers mainly through practical courses and with specific channels on the internet (agendagotsch.com; lifeinsyntropy.org). Estimates are that at least 5000 family farms have adopted this practice all across the country since then, and it has also been exported to other countries in Latin America (Bolivia, Colombia, Chile, Mexico), Caribbean (Martinique, Curacao Islands), Europe (Portugal, Spain, France, Germany, Italy, Greece), Africa (Mozambique), and Oceania (Australia). Syntropic agriculture bears elements present in most of the types of agroecology, such as no use of chemicals, no-impact or low-impact technologies, and a design strongly based on ecological succession. However, it differs from other agroecological practices for having the concept of syntropy as its main foundation, both for the interpretation of the mechanisms of life and for the decision-making process regarding management in the field.

Table 2

Evidences of economic feasibility of syntropic agriculture and other types of successional agriculture in Brazil

Main products	Ecoregion	Description of the case	Reference
Palm oil	Amazon	Smallholder farmers benefitted from adding short cycle (3 yrs) crops until palms started producing. Furthermore, when palm trees decline in about 25 yrs, slow growing timber and nut trees planted will be producing	[37]
Pineapple, banana, palm heart, citrus	Atlantic forest	Four succession-based agroforestry designs required 10 times less land to reach the same productivity and income per unit area than the region's conventional soybean, corn and milk operations	[38]
Tomato, pineapple, papaya, citrus, cacao, mahogany	Cerrado and Atlantic forest	Average yield projected for two syntropic agriculture plots were 16 and 21 $t.ha^{-1}.yr^{-1}$, whereas other agroforestry systems produced between 2 and 13 $t.ha^{-1}.yr^{-1}$	[39]
Horticulture, fruit, coffee	Cerrado	Payback of this successional system occurred after 1.1 month. In one year, benefits surpassed costs by 82%	[40]

Syntropy, that is, the tendency complementary to entropy, first appeared as a scientific concept in the 1942 publication 'The Unitary Theory of the Physical and Biological World' by Italian mathematician Luigi Fantappiè. According to Fantappiè, while entropy rules the mechanical and physical world, syntropy governs the biological world [23]. While the former is related to energy dissipation, the latter refers to energy concentration. Indeed, Ernst Götsch argues that syntropy and entropy are not in opposition, but in complementarity, 'as inspiration and expiration in the respiratory cycle' [24].

In general, agricultural innovations focused primarily on how to increase the efficiency of entropic processes of deassimilation and simplification (expiration), and devoted little attention to what happened in fallow areas (inspiration), where the activity of each generation of plants, animals and microorganisms delivered a more complex environment for the next generation. Organisms behave as open systems that overcome the tendency to increase entropy by converting environmental resources (food, oxygen, water) into growth, reproduction and differentiation. This capacity that biological systems have is reflected in hierarchically broader organisational levels throughout the evolutionary process, such as, for example, in the modification and adaptation of lineages to an ever-changing environment. This process culminated in the emergence of complex biological organisation structures on the planet. In short, while entropy governs thermodynamic transformations that release energy at the expense of complexity, syntropy accumulates and organises energy, for example, in organic molecules, which results in differentiation and complexity [25,26].

When syntropy is applied to agriculture, two nature-inspired processes are central: natural succession and stratification. The introduction of a diversity of plants in the cultivated system in time and space facilitates succession and results in stratification with different densities of vegetation layers in all successional stages. Layers of vegetation mean layers of photosynthesis. The gradual difference in layer distribution — denser at the bottom and sparser in the upper strata — works as a heat sink, a temperature gradient that helps maintain moisture in the soil. The optimisation of layer occupancy combined with constant soil cover reduces pressure from invasive plants. The syntropic farmer, therefore, replicates and accelerates the natural processes of ecosystem regeneration, placing each cultivated plant in their 'just right' position in space (strata) and in time (succession). Syntropic agriculture relies on ecological succession and stratification as a replacement for fertilisers and pesticides. In other words, it is process-based, as opposed to many conventional or organic practices that are input-based. To accommodate the coexistence and management of many species, in the conceptual framework of syntropic agriculture, cooperation and "unconditional love", as defined by Ernst Götsch, play a larger role than competition. These concepts challenge individualism and personal interest, which become entirely subjected to ecosystem functioning. 'Love', in this sense, places humans as part of the ecosystem's strategy to increase energy, having syntropy as premise. This is to a large extent in harmony with findings related to the process of transitioning from conventional to regenerative agriculture in Australia, where transition involved mainly subjective and nonmaterial factors related to emotions, culture and values [27••].

Most agricultural practices historically reveal the paradox and contradiction of meeting human needs versus maintaining the natural systems on which services society depend upon [2,28]. Whether by plowing or no till, polycultures or monocultures, chemical or biological intensification, agricultural technologies are often oriented to combat the inexorability of natural dynamics. On the other hand, the concept of syntropy applied to agriculture offers a new framework for interpreting the integration and interdependence of humankind and natural processes. Under this perspective, there is a resignification in the human-nature axis, which is a counterpoint to the very notion that, to achieve its production goals, the activity of farming depends on containing and excluding natural dynamics [29,30]. Quite the opposite, syntropic farmers bring those dynamics into their productive system, benefitting from it and overcoming the paradox between food production and environmental conservation. This innovation, in turn, has consequences in the technological epistemology – the third axis of the proposed tryptic. Management decisions — such as resource use (fertilisation, irrigation), pruning (what, how, and when), and consortia composition — will, in this case, be submitted to ethical and moral values oriented by syntropy interpretation of natural system functioning. Rather than rejecting technology, syntropic agriculture calls for new grounds on the technological innovation front. In the meantime, most operations in syntropic agriculture are still performed manually, which increases labour costs and proves challenging to large scale enterprises. To face this main limitation of syntropic farming, the development of low-impact technology is key to boost the scalability potential of this practice. For instance, a lightweight machinery set has been designed to help farmers establish and manage complex multi-story plantations and, at the same time, respond positively to environmental issues (for examples, see https://agendagotsch.com/en/peace-farming-technology-preparing-the-beds/). A second potential limitation of syntropic farming is related to the fact that the establishment of a biodiverse system requires specific planning and logistics. Farmers need forestry and agricultural materials of all successional stages at their disposal at the moment of implementation. They also need the necessary know-how to manage multiple species, which is less common than the specialised knowledge to deal with one or few species only. Despite these limitations, there is increasing evidence that syntropic agriculture can be economically feasible (Table 2).

Syntropic designs allow permanent soil cover, the maintenance of a constantly pruned stratified vegetation, optimisation of overall photosynthesis and biomass production. All of that reflect on prevention of soil erosion, increase in carbon sequestration, the ban of herbicides and the reduction of irrigation demand, stimulation of soil beneficial micro fauna, which replaces the need for fertilisers and defensives. The combination of these factors increases ecological and economic resilience, benefiting both farmers and the environment [31]. The development of lightweight machinery will be key to scale up this practice.

Conflict of interest statement

Nothing declared.

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