Agropedology

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Summary

An epistemology of the agronomic sciences is outlined from its birth in the 19th century, at the time of the Industrial Revolution. It began with the positivism inherited from the Enlightenment. As a science applied to the rural environment, it also took an interest in socio-economics. It then leads to systems thinking, reminding us that we are dealing with open, complex thermodynamic systems. Unfortunately, the systemic approach adopted, notably in the work of Dokuchaev, creates a schism between the soil system and those of production lines of culture, pasture and forestry. An unofficial interdiscipline, that of agropedology, provides the link between pedogenetic processes and current topsoil characterization and the other systems, thanks in particular to a more technical classification of soils. However, the geographical unity of landscapes is being lost. A solution can be found in the ancient concepts of *ager*, *saltus* and *silva*, which unify the various systems under consideration. The urban environment (*urbs*) and its parks and gardens (*hortus*) are also added. These powerful ancient concepts lead to the new paradigm of "landgenics". Agropedology is set to play a key role in this new paradigm, and should become an integral part of the curriculum for agricultural engineers.

1. Introduction

Epistemology of the agricultural sciences follows the general trends observed from the reductionism inherited from the Enlightenment to today's approach of complex, thermodynamically open systems (e.g. global terrestrial climate, ecosystems). It follows a positivist, analytical path from factors and variables that act independently of one another to the identification of units of interacting factors and variables, the holons, and their modes of evolution. Although the components were initially well identified, a compartmentalized, reductionist approach took over. As the number of factors and variables increased, the complexity and dynamics of the very object of agronomy were revealed by agropedologists.

Positivist epistemology of Auguste Comte (1798-1857) points to three modal foundations in science (LECOURT, 2001, chap.4). First, there is the positivist thesis, which focuses on discovering the actual laws of phenomena. Then there's the rational prediction that laws allow. And finally, the foresight thesis, which supports the notion of application. Positivism is therefore based on determinism as a succession of states or sequence of events in natural phenomena, but excluding any mysticism. BRICMONT (2012) points out that determinism should not be confused with predictability, as everyone admits that many things are unpredictable.

An important epistemological step has been taken with systems thinking. In this new paradigm, the holistic principle of interaction and complexity stands in opposition to Cartesian reductionism. In addition to interaction, which undermines determinism, the notions of organization, globality and complexity become essential. This led to the development of the "holon" concept, borrowed from KOESTLER (1969) to designate, according to LE MOIGNE (2006), "*unbreakable aggregates*", "*irreducible and polyfunctional processors such that if they are made to intervene to perform one function, they ipso facto lead to the potential activation of all their other functions*".

Deterministic models pose real problems for complex systems with multiple interactions and non-linear dynamics, which is the case in all living phenomena. MANSON (2009) distinguishes three types of complexity research. Algorithms measure the structure of systems in terms of the computational processes required to reproduce them. Deterministic complexity explores mathematical variables in terms of non-linear dynamics and chaos. And finally, aggregate complexity analyzes the emergence of systems based on the interactions between their components.

If foresight is a positivist quality, and they give rise to the new social class of engineers, we need to distinguish civil engineers from agronomic engineers. The latter are confronted with the living, i.e. with biology and with "social", directly with complex dynamic systems, usually approached in an aggregate manner. Like doctors, agronomists are practitioners of the living world, not only at the level of agronomic practices, but also at the more moral level of collective well-being. GRANGE (2000, p.246) points out that doctors give a human and social meaning to science. The same applies to agronomists.

Geography is also challenged by holism and systemics, in reaction against reductionism. It is effectively confronted with the "used territory" and all the socio-territorial actors and processes that work and interact there globally (BERNARDES et al., 2017).

We describe the agronomic object, starting with its epistemological foundations and conceptual holon. Next, we briefly present the reductionism applied to soil, cultivation, grazing and forestry systems. A return to the interesting ancient concept of *ager*, *saltus* and *silva* allows us to group all these systems in relation to the deployment of towns (*urbs* and *hortus*) at a very general but also very practical landscape level. Finally, the new holistic approach of landgenics is evoked to rationalize the interactions of these agropedosystems and paves the way for the integration of geographers' "used territory".

2. The agronomic object

The agronomic object is the anthropized ecosphere following the domestication of plants and animals. It is divided into several compartments: the atmosphere, the biosphere, the hydrosphere and the lithosphere. The biosphere can be reproduced as an anthropized biotope or anthrobiota, as shown in the conceptual holon in Figure 1. It represents the unit where internal interactions between compartments or major components (vertical arrows) are strongest, while laterally they are weaker (horizontal arrows).

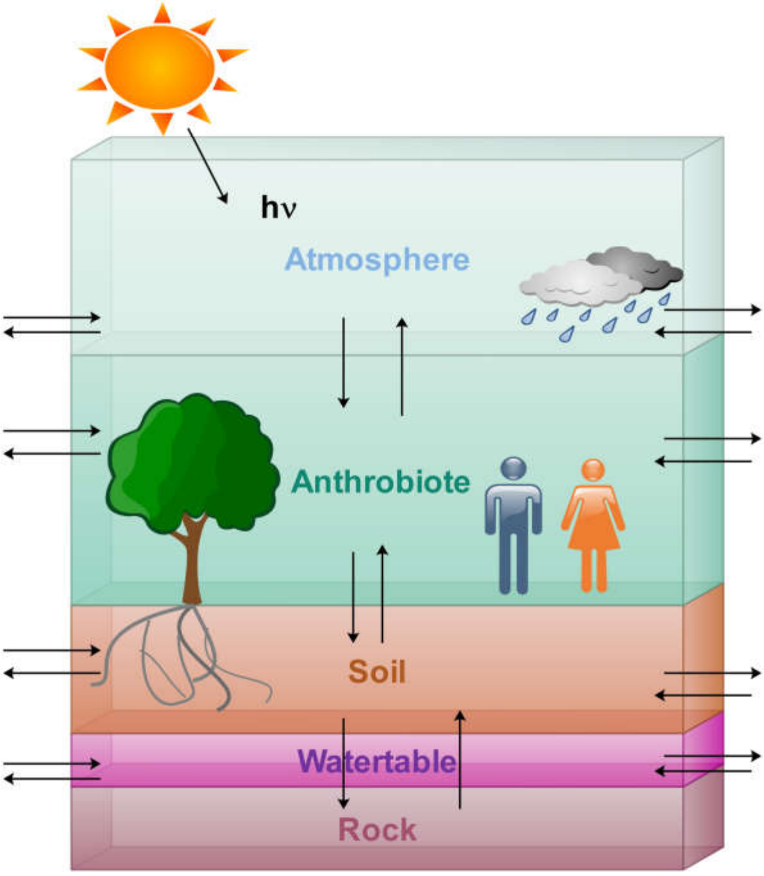

Figure 1: schematic representation of the holon as the central conceptual object of agronomy

The various compartments of this general concept form an indivisible whole. Plants cannot be separated from their roots, leaves cannot be separated from atmospheric CO_2 and O_2, soil cannot be separated from infiltrated rainwater or groundwater, nor from the rock from which it is derived, roots cannot be separated from O_2 and soil water, leaves cannot be separated from their source of solar energy (hv), and so on. The agronomic object has the status of an open thermodynamic system, away from equilibrium, thanks to its openness to space (solar and cosmic rays, meteorites) and to the deep underground world (groundwater, volcanic magmas, rocks). It's also clear that this conceptual holon is open, especially around its edges, to ensure the continuity of geographic space and the migration of plant diaspores, animal movements, surface waters and detrital materials. As an open thermodynamic system out of equilibrium, it allows numerous local entropy increases, such as those of all living beings in the biosphere, geomorphological and hydrological formations, atmospheric gas convection, cyclones and anticyclones, etc.

Lastly, agronomy is concerned with feeding people and their domestic animals. It also provides them with materials such as timber and firewood, textiles, hides and skins, ornaments for gardens and parks, natural medicines, perfumes, plant essences and so on. It occupies more than 99% of the world's huge landmass, and is also used to build means of transport, villages and towns.

3. Historical reductionism in agronomy

According to BOULAINE and GROS (1998), quoted by PAPY (2008), agronomy was born in the mid-18th century with the popularization work by DUHAMEL DU MONCEAU (1750-1759), inspired by Jethro Tull's theory of plant nutrition and principles of cultivation. Tull considered mineral soil as an endless source of nutrients.
But according to DENIS (2004), if we refer to agronomy, in its broadest sense, as the field of various sciences applied specifically to agriculture, the term was not used as such in France until the mid-19th century by DE GASPARIN (1843) and AMPERE (1834).
Modern agronomy was thus born at the time of the industrial revolution.
The first agronomic research stations were established in 1843 in Great Britain (Rothampsedt), 1850 in Germany, 1868 in France (Nancy), 1877 in the Netherlands (Wageningen) and 1887 in the USA. They based their work on the mineral nutrition of plants proposed by Justus Liebig in 1840 and THAER's humus theory (1809-10). The latter defined agronomy as the study of soil and agricultural land.

Perhaps inspired by this theory, a particular but reductionist discipline has emerged, pedology, which is specifically dedicated to soil. Soil is a complex, multi-component object with both spatial and temporal (dynamic) variability. In Russia, Dokuchaev promoted the image of soil as a natural body. In 1900, he published the country's first pedological map. From 1900 to 1960, during the colonial period, a major effort was made by soil scientists under the leadership of Georges Aubert in France to study soil genetics, characterization and mapping, and by agropedologists to study the influence of soil properties on agricultural use. AUBERT (1941) points out, however, that "*agronomists are only interested in the soil as a growing medium. They consider its current physical and chemical state, rather than how it was formed. Its past history is studied only insofar as it enables us to understand this present state and its future evolution*".

To the reductionism of the discipline was added a reductionism in the conception of the soil, namely the branch of its characterization, later taken over in France by CIRAD, and that of its "genetic" evolution taken over by ORSTOM. TOURTE (2005) once again points out that to maintain the links between the two branches, it will be necessary to invent an intermediate category of researchers known as agropedologists.

3.1. The soil system

CHATELIN (1972) recalls the predominant role of genetics as the foundation of the discipline of soil science, as originally established by Dokuchaev. He describes the classification of soils in order to define a general typology. The latter requires a large number of variables, such as

carbon content, climatic and hydrological regime, effective cation exchange capacity, basic cation saturation rate (Na, Ca, Mg, K), etc., to be taken into account. In its conception, this classification is indeed systemic since multiple variables or factors are considered, whether geochemical or indirectly geomorphological.
CHATELIN (op.cit.) distinguishes three types of classification: selective, summative and pangnosic. Selective classification operates by successive sorting, dividing up the various taxa according to very different criteria, such as those used in D'Hoore's map of African soils. In the summative approach, each category is diagnosed by gathering as much data as possible, with the USA classification as an (imperfect) example. Finally, the pangnosic one aims to provide a more or less direct and explicit understanding of the genesis and intrinsic characteristics of soils in their totality, using the Soviet classification as an example.
But the question in agronomic science is: what does this typology lead to? Indeed, it seems to boil down to the identification of taxa, just like the systematics of living organisms, with a rather vague notion of its past and sometimes future evolution?

Alongside the natural scientific classifications of soils, there is a more technical classification in which soils are grouped according to the types of potential problems they may pose for their agronomic management, in the identification of systems of forestry, grazing or cultivation. This is the classification used by SANCHEZ et al (2003). It is a summative classification with two types of attributes. The first relates to the materials making up the surface and deep parts of the soil, according to whether they are organic or mineral, as shown in Box 1.

Box 1: Attributes of soil materials according to SANCHEZ et al. (op.cit.)

Soil material is considered organic (symbol O) if the organic carbon content remains above 12% between 0 and 50 cm depth.
For non-organic material, the surface granulometry (0-20 cm) is taken into account. A distinction in 3 classes is adopted, symbolized by capital letters: "sandy" (symbol S), groups together the SOIL SURVEY STAFF (2014) classes of sand and loamy sand; "loamy" (symbol L), clay < 35% except sand and loamy sand; "clayey" (symbol C), clay > 35%.
If a class change occurs before the 50 cm depth, a second grading symbol is added to the first: "sandy" (S), " loamy" (L), "clay" (C), rock or other hard material limiting root development (R). If this indurated layer can be dismantled mechanically, the symbol "R^-" is used.

The second type of attribute is made up of 17 modifying conditions for the constituent material. They are indicated with their symbol in brackets in Box 2.

Box 2. Soil attributes according to the modifying conditions of the constituent material according to SANCHEZ et al. (op.cit.)

seasonal aridity (d), low mineral nutrient reserves (k), high erosion risk (%), aluminic toxicity (a), high phosphorus fixation (i), poor drainage (g), highly leachable (e), calcareous (b), swelling clays (v), gravelly/stony (r), low loose depth (1st symbol = R), saline (s), sodic (n), amorphous volcanic (x), organic (1st symbol = O), sulfidic (c), permafrost (t), organic carbon deficit (m).

With this technical classification, the agropedologist is strengthened in his role of interpreting pedological data at local level to provide useful information from the point of view of agronomic land management.

3.2. Cultivation, grazing and forestry systems

In the mid-nineteenth century, at the advent of agronomy as a science, DE GASPARIN (1849), quoted by PAPY (op. cit.), defined the cultivation system (CS) as a "choice of procedures for exploiting nature" with varying degrees of intensity. By referring to processes for exploiting nature, DE GASPARIN brings agronomy closer to ecology, and implicitly includes the nature of the soil in the selection criteria. PAPY specifies that it refers to agricultural operations that constitute a cultivation in the sense of a type of land use, and not to the cultivation as a whole production unit. This definition makes it possible to classify different cropping systems according to their increasing degree of anthropization, from forestry systems to those using "physical and chemical means other than those of nature". We can therefore see that forestry and even natural uses, the latter as a choice to refrain from implementing exploitation processes, are included in the very broad concept of CS.

However, PAPY points out that the modern formulation of CS by SEBILLOTTE (1974) is more refined, and combines the choice of species and the cultivation methods or "technical itineraries" applied. We can also distinguish between grazing systems (GS) and forestry systems (FS).

GS is a part of the ecosphere in which one or more units of specific, perennial vegetation, grassy or shrubby, are used for grazing by one or more herds of cattle, sheep or goats. The GS thus has a triple constitution: "soil-vegetation-herd". It is a type of "non-arable" forage land, used more or less intensively for grazing by itinerant or sedentary livestock farmer. Pasture following a short period of non-fodder crops in rotation will, however, be included in the corresponding GS. As such, the GS and CS are part of the UAA (useful agricultural area).

The concept of forest system (FS) is based on a set of interactions between a forest "stand" and its "reference station". Forest stations are representative of the various stands in a given massif. They include a reference to a soil or terrain in relation to the stand's phytosociological association. The latter is the woodland unit, the basis of forest perception. It's a relatively homogeneous part of a forest, clearly identifiable by the spatio-temporal arrangement of its constituent trees. The forest station is an area of land with homogeneous physical (climate, topography, bedrock, soil) and biological (vegetation dynamics) conditions. The station is identified on the basis of its phytosociological unit, determined by its indicator plants and soils. It is also based on its relief, i.e. altitude, slope, exposure and landform.

3.3. Back to the ancient agrarian trilogy in the landscape

When the soil system is grouped together with cultivation, grazing and forestry systems at a more or less homogeneous local or regional landscape level, we rehabilitate the ancient agrarian trilogy evoked by RAYNAUD (2003). It subdivides land use according to its main orientations. These distinctions theorize the landscape of societies marked by the growth of the urban phenomenon. *Ager* (and *Hortus*, horticultural land) constitute the cultivated and more or less regularly tilled part, equivalent to what we call arable land, while saltus and silva designate the "uncultivated" or non-arable part. VIDAL (2011) reproduces an idealized concentric diagram around the urbanized *urbs* zone, as shown in Figure 2.

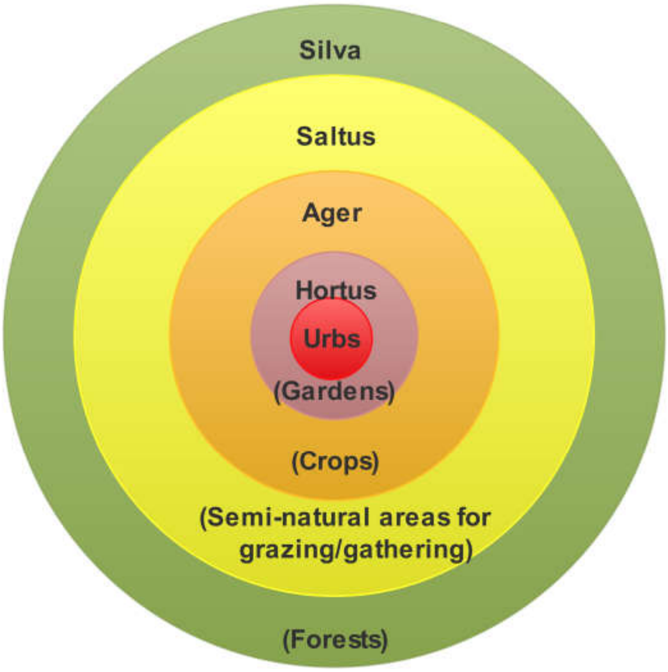

Figure 2: The ancient agrarian trilogy of *ager, saltus* and *silva,* completed by the *urbs* built-up areas associated with hortus

POUX et al. (2009) explain these different components. *Silva* is a closed wooded space, encompassing plant formations perceived as primary and described as "wild" by VIDAL (op. cit.), but also today spaces dedicated to silviculture. *Ager* is the cultivated, planted or seeded domain, and also includes vineyards and orchards, and therefore also more generally perennial agricultural plantations. Finally, *saltus* is a semi-natural formation, but one that is still under human management. It comprises all uncultivated open spaces and is generally used for herding and gathering. In *saltus*, POUX et al. (op.cit.) consider that fertility reproduction is natural. It is ensured by the looping of nutrient cycles with no external inputs. In the *ager*, on the other hand, fertilization of cultivated plots is carried out on a more or less regular basis.

4. How can agropedo-systemic interactions be rationalized?

Interactions of forestry, grazing and cultivation systems with the soil system are self-evident, not only in *ager* but also in *saltus* and *sylva*. How can we identify, understand and exploit them agronomically, and anticipate alternatives to meet future food and ecological challenges? In fact, the habits and customs of farmers, herders and foresters have already established these relationships through trial and error, empirically. They are the fruit of the experience of many generations since the advent of the Holocene. The fact remains, however, that many unknown factors were not scientifically established. Agropedologists have identified variables or factors, several of which are cited in Boxes 1 and 2 of the technical classification by SANCHEZ et al. (op. cit.).
OPDECAMP (2023) provides the scientific underpinning for factor "a" in Box 2, namely that of soil aluminization in shaping landscapes in humid tropical and temperate regions. Soil aluminization and its variable durations are described, and its degree of progress specified according to a Kamprath "m" index. The effects measured on the growth of numerous plants, both cultivated and non-cultivated, and on biodiversity are explained, from the scale of biology to that of ecosystems and their agropedological holons. BERNARDES et al. (op.cit.) "territory-used" actors are also integrated into the holistic landgenic model.

5. Conclusions

Positivism inherited from the Enlightenment left its mark on agronomy right from its birth during the industrial revolution of the 19th century. It was based on the natural link between the anthrobiota and the soil as a resource of water, mineral and organic salts and oxygen for plant roots. This fits in well with the image of the conceptual holon.

With the development of systemics and the interaction between components, agronomy has developed several systems and made a split between the soil system and the cropping system in the broadest sense (crop, grassland, forest). Soil has thus become an object in its own right, the study of which is based on its pedogenesis, classification and mapping. It also showed a certain lack of interest on the part of agronomists (not soil scientists), who were focused on sectors and not at all on the pedogenetic mechanisms at work in landscapes. To establish the link between these two major disciplines, we turn to the interdisciplinarity of agropedology.

In the end, it's by going back to the trilogy of ancient agrarian design that we rediscover this interest in landscape, with the concepts of *ager*, *saltus* and *silva*, where the development of cities (*urbs*), parks and gardens (*hortus*) fits in. And it's by using them that we can return to a more holistic, geographical conception of agronomy. The aim is to bring together all the players in the geographer's "used territory", according to the new paradigm of landgenics.

Agropedology should play a key role in this. It is therefore recommended to make it a teaching discipline to refine the useful variables and factors intimately linked to cultivation systems in *ager*, grazing systems in *saltus* and forestry systems in *silva*.

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