A crop model as an "intermediary object": Lessons from a participatory research on the agronomical bases of PGI Corsican Clementine typicity

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Abstract: In this article, we build on an on-going participatory research conducted in Corsica to report the use of a heuristic cropping system model as a mediating tool to assist researchers and actors in the understanding of a challenging scientific problem: The agronomical determinism of the acidity of Corsican Clementine, acidulous taste being a strategic typicity attribute for this terroir product. The collaborative research included the participative conception and refinement of an acidity model, the use of the model to design an empirical validation method called Regional Agronomical Diagnosis (RAD), and the up-coming use of RAD's first results to refine the model. Iterations between actors' knowledge, model, and farm survey may continue in the 2 following Clementine campaigns, leading to a step-by-step convergence between model and reality. Our acidity model opens up perspectives for Corsican stakeholders, since it could be used in further participatory research to design innovative cropping systems in adaptation to emerging challenges such as climate change, or new varieties. However, the use of a model to understand an agronomical variable or to orientate field observation is not new. What is new is the fact of using such model as an intermediary objet in a participative device. Through its intrinsic infrastructure, the model structured interactions between actors, researchers, and experimental device, and it enabled convergence of representations between opposed epistemological postures. If the model appeared to be predictive, it would suggest that in localized agri food systems, local knowledge are crucial resources which can be channeled by researchers by using intermediary objects as mediating tools in the perspective of addressing complex scientific problems.

Keywords: Clementine, acidity, cropping systems, participatory research, intermediary object

Introduction

Understanding agronomical bases of typicity: a challenge for SYAL stakeholders

Localized agri-food systems' sustainability relies on the capacity of its stakeholders to emphasize and maintain products typicity through qualification processes. A poor understanding of agronomical bases of typicity can put localized agri-food systems into a position of vulnerability, especially when broad changes such as climate upheaval affect GI production area. In the case of non transformed agricultural products, such links are difficult to establish because products quality depends on numerous and complex factors (e.g. climate, soil, agricultural practices). This article introduces methods and first results from a participatory approach employed by researchers to build a shared understanding of the typicity of a terroir product: the Corsican Clementine.

Interest of participatory approaches in agricultural science

An epistemological and social revolution led to the recognition of stakeholders' knowledge and skills as legitimate to contribute to research problems resolution (Gasselin & Lavigne-Delville, 2010). This idea has spread in agricultural and rural development research, and it is increasingly recognized that participatory approaches based on local knowledge are an option if sustainability and development goals are to be reached (IAASTD, 2008). Thus, participatory approaches are mobilized in a diversity of thematic contexts. To give just a few examples, such approaches are often mobilized in farming system research, livelihood systems studies, participatory plant breeding, or diagnosis and design of cropping systems (Sellamna, 2010). Collaborative approaches are often combined with cropping system research in the understanding of unsatisfactory agronomical performances or in the design of innovative technical itineraries (Lavigne et al., 2004).

A heuristic model as tool of participatory research structuration

Researchers mobilize a diversity of tools in participatory approaches, ranging from simple artifacts (cross-tabulation, map, black board) to complex models. In this article, we report the use of a heuristic crop model as a mediating tool to assist researchers and stakeholders in the understanding of a challenging scientific problem: The agronomical determinism of the acidity of Corsican Clementine, acidulous taste being a strategic typicity attribute for this terroir product. The article shows that the model acted as an "intermediary object" contributing to knowledge co-elaboration, and to the convergence of actors' representations on the acidity determinism. The main function of the model was to structure mutual exchanges between actors, researchers, and an experimental device. It did so by providing a normative – and evolving – framework channeling heterogeneous actors' inputs, driving empirical observation, incorporating field observations, and by allowing constructive dialogue between holists and reductionists.

Analytical framework of the model's role in the participatory process

To understand the model's role, we analyzed our participatory research as a process along which multiple interactions between and among actors, artifacts, and institutions led to the convergence of actors' representations on fruit acidity determinism, and to the generation of new knowledge.

First, to analyze interactions between actors, researchers, and experimental device, we considered the acidity model as an "intermediary object" carrying embedded rules, which acted as a frame enabling and constraining perceptions, interactions and inputs during the participatory construction. The concept of "intermediary object" forms part of a research tradition putting emphasis on the materiality of things in social sciences. It especially inherits from the actor-network theory (Callon, 1986, Latour, 1994), and the notion of "boundary object" (Star & Griesemer, 1989). According to Vinck (2009), intermediary objects are material or immaterial artifacts that are produced, mobilized, and exchanged by actors, and which participate in framing action and interactions through processes of representation, translation, and mediation. Recent works have reported the use of intermediary objects to analyze or monitor situations of mediations between heterogeneous actors (see Lardon et al., 2001 for an illustration). In this article, we analyze how the rules embedded in an intermediary object (a crop model) could structure mobilization of local knowledge by researchers in a participative process.

Then, to assess to what extent the model had contributed to the convergence of actors' representations on fruit acidity determinism, we compared the initial perception of each actors' groups with the final shared understanding synthesized in the model. Initial perception of each actors group was analyzed in the light of sociology and institutional theory. For each group, we identified patterns of institutions which shape awareness and interpretation of reality, and coordinate in return actors' perception of and knowledge on acidity determinism. We used the distinction proposed by Scott (1995), between regulative rules (i.e. explicit and formal rules such as laws), normative rules (i.e. internalized through social process such as norms or professional identity) and cognitive rules (i.e. the frame through which meaning or sense is made, such as paradigms and ontological posture).

The development of this article is organized as follow: In part 2, we explain how has emerged the Corsican Clementine acidity issue. In part 3, we describe the construction of the participative research (actors, main steps, and experimental device). We then introduce the outcoming acidity model (part 4). In part 5, we analyze model's contribution to the structuration of interactions between actors, researchers, and experimental device, and to the convergence of actors's representations on fruit acidity determinism. In part 6, we discuss possible implication of the use of crop models to strengthen participatory approaches.

Emergence of the Corsican Clementine acidity issue

Acidity: A crucial but poorly understood quality attribute for Corsican Clementine

Corsican clementine has been recognized as a PGI in 2007, leading to a revival of the sector after a period of decline in the 90s. The reputation of the "Clementine of Corsica" is due to several criteria of fruit quality such as the presence of long leaves in fruit crates, a specific color, and a slightly acidulous taste. As foreign competition increasingly imitates external attributes of Corsican clementine (e.g. presence of leaves in crates), the long term success of the PGI relies on the capacity of local stakeholders to strengthen and sustain other attributes of specific quality, first and foremost the high acidity level. Moreover, the process the defense and management organization recently embarked to obtain a red label makes it all the more urgent to understand the bases of fruit acidity, since the red label specification requires even lower variability and higher threshold in fruit acidity.

Although local stakeholders agree that "slightly acidulous taste" is a crucial typicity factor for Corsican Clementine, fruit acidity has remained an unchecked parameter in cropping systems and individual farmers' strategies. This paradox results from a lack of knowledge on the agronomical bases of fruit quality among farmers, extensions, and scientists. This is probably explained by the historical trajectory of local agricultural innovation system, which partitioned fruit quality questions into the field of varietal innovation, leaving aside cropping systems aspects. Moreover evidences show that there are a significant spatial, intra and inter annual fluctuations in fruit acidity within the PGI zone, as well as an effect of agricultural practices on acidity (Belmin, 2013).

The Corsican Clementine GI area under broad changes

In a context of global changes affecting the PGI zone, this difficulty in objectifying the combined role of climate, soil and practices in the construction of fruit acidity challenges Corsican stakeholders. First and foremost, Mediterranean zone is affected by climate change, with suspected consequences on Corsican clementines' acidity (Pailly; 2014). The 2013 IPCC report indicates that in this geographical area, observed changes since the middle of the 20th century include an increase in droughts' frequency and intensity, extreme precipitations, as well as a decrease in cold nights and frosts. On their side, local farmers and experts assert that fruit acidity is trending down for around 15 years, due to climate upheaval. However, as far as we know, no available scientific data could demonstrate a decrease in Corsican clementine acidity, nor any link between climate change and clementine quality variation. The fact remains that a possible trend reduction in fruit acidity caused by climate change is a rising issue in the PGI area. Climate is not the only broad change affecting production basin and (possibly) fruit quality. There is a quick evolution of agricultural practices with yield and fruit size as the main cropping system performance criterion. These technical changes include annual pruning, weed management, fertilization, as well as harvesting methods. PGI Clementine quality change may also be driven by new varieties and root stocks such as SRA535 or tetraploid root stocks. Such changes are also possible because the PGI specification provides a flexible frame, leaving room for much variability in agricultural practices.

A participatory research to understand Clementine acidity variability

Researchers implemented in 2013 a participatory research aiming at better understanding the variability of Corsican Clementine acidity. The participatory research included actors' mobilization, the co-conception of a heuristic acidity model, the use of the model to design an empirical validation method called Regional Agronomical Diagnosis (RAD), and the use of RAD's first results to refine the model. Thus, knowledge on fruit acidity was constructed and refined through organized iterations between model, actors, and on farm survey.

Creation of a participatory device

We began by designing a participatory research device involving a diversified panel of actors chosen according to their current or historical function in the clementine production basin (**Table 1**). The core of the device was a working group involving citrus consultant, technicians, agronomists, and researchers from 2 disciplines (ecophysiologists, and geneticists). Interactions with working group's members included 3 workshops as well as individual interviews and field visits. In parallel we consulted 13 farmers through individual interviews, field visits, and participant observation.

Participatory conception and refinement of a heuristic acidity model

In a first workshop, we identified possible acidity drivers through brainstorming. Participants were asked to say what are, according to their empirical or theoretical knowledge, the main factors involved in the variability of Clementine acidity. The information gathered during the workshop was complemented through individual interviews and field visits with farmers, technicians, and experts.

In a second step, we integrated data into a first conceptual crop model. The various data collected so far were graded and organized in an agronomical model, mobilizing and adapting concepts such as yield components (Boiffin et al, 1981, Meynard & Sebillotte, 1982) and yield elaboration compartments (Sebillotte, 1995). Inspired by the notion of yield component, we divided the elaboration of final fruit acidity into simple components whose formative period is shorter than the one of final production, and that only depend on a limited number of factors. Acidity components were considered as (semi) independent variables, well identified in the tree cycle. The various factors influencing acidity components were identified, and placed together with the components themselves into 5 interacting compartments: climate, permanent environment, non-permanent environment, agricultural practices, and physiological status of the tree. This first-generation model was then confronted with stakeholders' knowledge through a second workshop and using bilateral meetings. The information collected so far led us to build a second-generation model by introducing new acidity components, and by clarifying the factors influencing each component.

Table 1: Main function of the participatory research device's actors

Actors type	Number	Function in the production basin
Farmers	13	Farmers run capitalist exploitations of 10-20 hectares of Clementine, often associated with secondary crop such as grapefruit or kiwi.
Technicians	6	Technicians are employed by cooperatives, farmer groups, or chamber of agriculture. The main part of their work consists in following up individual farmers, and providing technical advice on pest management, fertilization and irrigation regime.
Citrus consultant	1	Citrus consultant is a highly skilled consultant providing extension to farmers and technicians in Corsica and in all Mediterranean area. He is used to intervene on questions of variety and root stock choice, pruning methods, and pest management. Citrus consultant has developed his skills through variety/root stocks evaluation in experimental or farmers plots.
Agronomists	2	Agronomists are employed by R&D "farmer-oriented" organizations. They implement ex situ experimentation programs to assess the effect of single technical acts on yield, caliber, and fruit quality. They currently develop and spread innovative weed and pest management techniques derived from agro ecological approaches.
Researchers	2	Researchers are geneticist and ecophysiologist employed by public "publish-oriented" organizations. Geneticist produces scientific knowledge on citrus genome and phylogeny, and selects new citrus rootstocks and varieties responding to identified challenges (disease resistance, yield, caliber, fruit quality). Ecophysiologist produces scientific knowledge on complex interactions between genotypes, phenotypes and environment in citrus.

Use of the model to design a regional agronomic diagnosis

The revised heuristic acidity model was used as an input to co-construct an empirical validation protocol using an approach called Regional Agronomical Diagnosis (RAD). Boiffin et al (1981) and Doré et al. (2008) introduced RAD as a methodological framework for identifying and ranking limiting factors for crop yield (or other variables relating to crop quality and environmental impact) on the regional scale : RAD consists in monitoring a set of measurements in a network of fields cultivated by farmers using current cropping practices. Thus, we mobilized RAD approach in the context of a participatory process, so as to test and refine heuristic model, and to identify the factors explaining the variability of fruit acidity. During the second workshop, stakeholders were introduced to the RAD approach, and they were asked to propose selection criteria's for plots as well as concrete field observations. Researchers structured the discussion using the second-generation acidity model as a starting point. 21 plots were selected and field observations were conceived so as to characterize each acidity component, as well as the main factors suspected to influence them.

Use of regional agronomic diagnosis' first results to refine the model

In the near future, concrete observations through RAD will lead researchers and working group participants to criticize the second-generation model, and build a third generation model. In turn, this will contribute to the improvement of field observation procedure for the next campaign.

In conclusion, actors were mobilized by researchers in the co-elaboration of 2 successive generations of acidity model: A first model was constructed by incorporating actors' inputs into a crop system framework. A second generation model was then constructed by confronting first model to actors' knowledge, and used as a starting point to conceive an on-farm survey using RAD approach. The up-coming third generation of model is to be constructed through confrontation between second generation model with first results from RAD. These iterations between model, actors knowledge and farm survey may be implemented again in the 2 following Clementine campaigns, and lead to a step-by-step convergence between model and reality. To the top of our knowledge, it is the first time RAD is conceived through a participatory approach, on the basis of a crop model constructed itself through a collaborative work. Nevertheless, the idea that actors' knowledge is valuable in such inductive approach was already there. Doré et al. (2008) mentioned that an option for researchers carrying out RAD is to integrate the farmers' knowledge into the identification of relevant measurements, and into data interpretation.

Introduction to the model

The second-generation acidity model took the form of a semi coherent set of hypotheses regarding acidity components, their interactions throughout the tree physiological cycle, as well as the various factors influencing the variability of each component. In other words, the variability observed in fruit acidity could be theoretically explained by the condition of elaboration of a limited number of semi-independent processes or "components" (noted C1-C8 following the order in which components were identified in the participatory process) well identified in the tree cycle, each component being driven by specific factors. According to the model, acidity of the fruits from a given parcel results from the meeting of harvest dates (C4) and % fruits harvested at each date (C5) with a long process of acidity decrease (C1) in a diversified cohort of fruits showing a wide range of sizes (C7), maximal acidity reached before ripening (C2), and coloration date (C6). Harvest dates and % fruits harvested at each date are partly constrained by coloration process. Maximal acidity reached before ripening and fruit size repartition are driven by flowering dates (C3), and by the number of fruits per tree (C8). Thus, C1-C8 are observable acidity components, which interact along the tree physiological cycle. The construction of each acidity component is driven by observable stages, processes, or interactions, occurring all into the 5 interacting compartments of acidity elaboration listed below (see **Figure 1** for a schematic representation, and **Table 2** for exhaustive model):

- **Physiological status of tree (PS):** This compartment gathers physiological status or processes directly or indirectly involved in the variability of acidity components.
- **Non permanent environment (NPE):** This compartment gathers elements from environment which directly regulate tree's physiological status, and which may fluctuate at the month time-scale under the influence of climate and agricultural practices.
- **Climate (CLIM):** Climate influences physiological status of tree through modifications in non-permanent environment (e.g. rainfall influences soil water availability).
- **Agricultural practices (AP):** Together with climate, agricultural practices influence physiological status of tree through modifications in non-permanent environment (e.g. fertilization modifies mineral availability in soil), or even directly (e.g. pruning).
- **Permanent environment (PE):** This compartment gathers cropping system elements which may not move at the time scale of the research, and which have effect on the interactions between the four other compartments (e.g. density of plantation, soil permeability).

Figure 1: Representation of acidity components as described in second-generation model

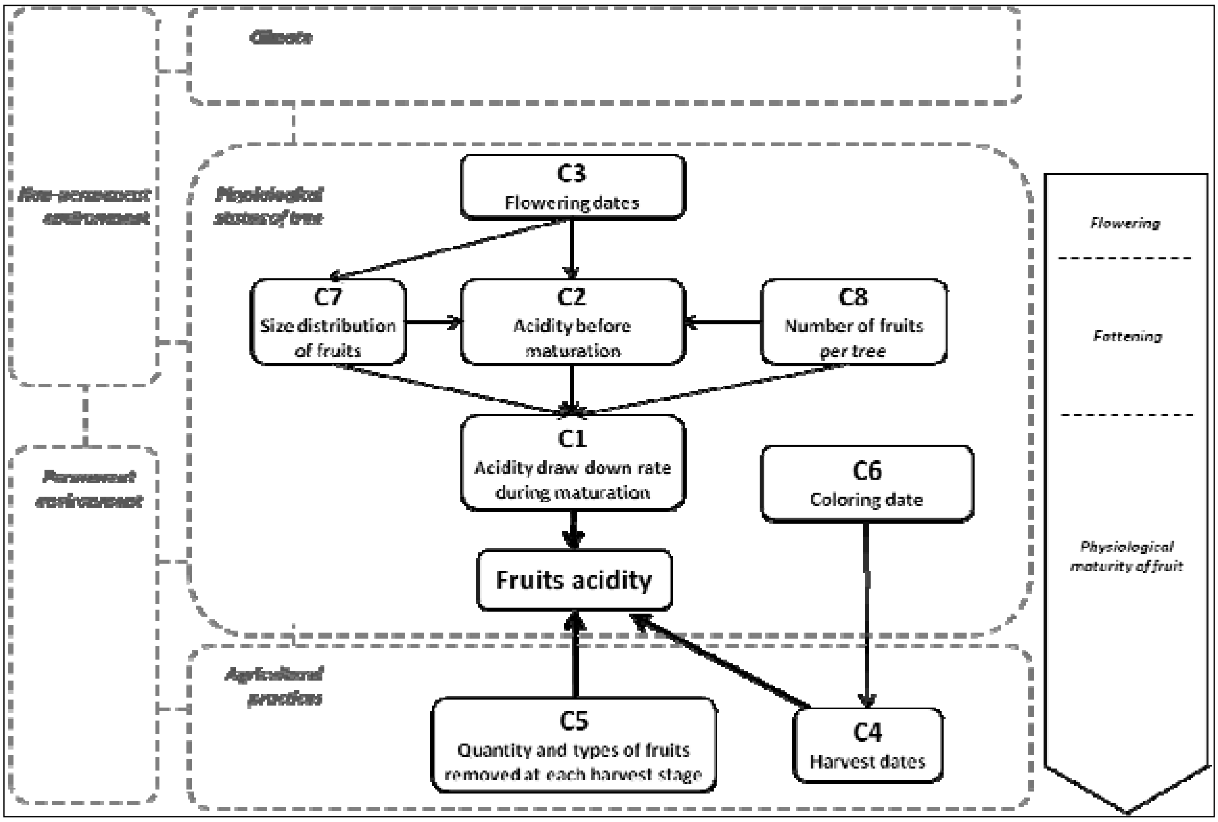


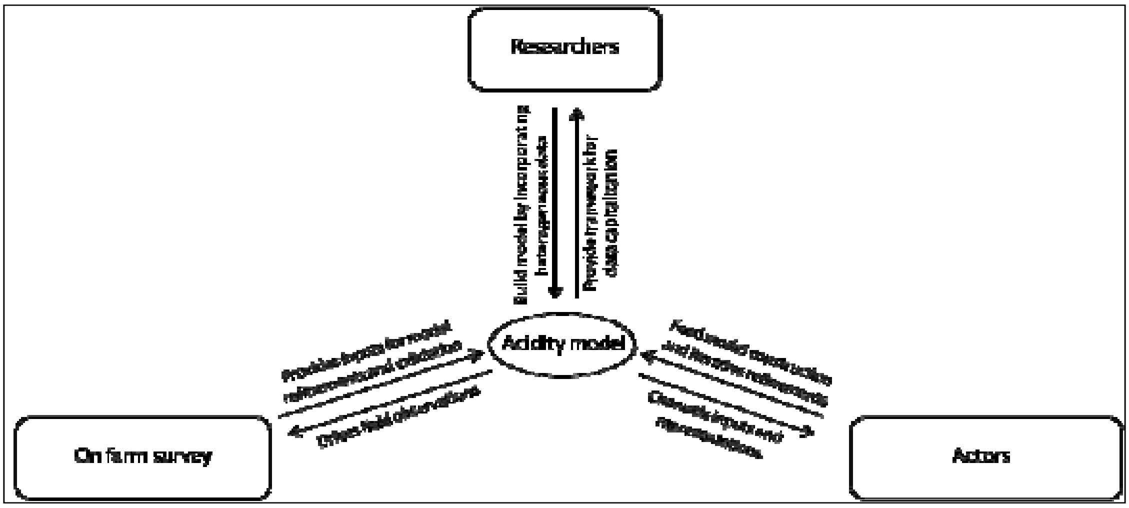
Table 2: Acidity components and the factors determining components variability

Acidity components	Corresponding biological or agronomical process	Factors directly involved in components variability	Other involved factors
C1 – Acidity draw down rate during ripening	C1 determines field-side fruits' acidity because during fruits' ripening, citric acid concentration decreases through cellular respiration.	C1 is accelerated by plant water nutrition during the ripening period (PS*).	**Plant water nutrition** is driven by rainfall and mild temperatures (CLIM*), soil permeability, slope, deepness of rootlets (PE*), grass cover, orchard temperature (NPE*) Irrigation regime, grass management (AP*)
C2 – Acidity before ripening	C2 determines field-side fruits' acidity because it constitutes the starting point for the following acidity decrease. During the filling period, acidity increases through citric acid accumulation in fruit's endocarp cells. Before the beginning of fruit ripening, total acidity content reaches its peak.	C2 is accelerated by temperatures accumulation above 13°C during the filling period, and also depends on plant water and mineral nutrition (PS*).	**Temperature accumulation** is driven by rainfall and temperatures (CLIM*), and by factors conditioning lightening and temperature accumulation in PE* (obstacles to light, orientation of rows, density of plantation), NPE* (deepness of rootlets, grass cover) and AP* (pruning type, grass management, irrigation frequency). **Plant water nutrition**: (see above). **Mineral nutrition** during filling period is driven by nitrogen absorption and by energy expenditure during previous physiological stages (e.g. flowering) (PS*). Nitrogen absorption depends on the factors regulating soil nitrogen availability (NPE*). These factors are found in AP* (fertilization and irrigation regime, grass management), NPE* (competition with grass cover, soil temperature), and CLIM* (rainfall and temperatures).
C3 - Flowering dates (beginning and end)	C3 determines field-side fruits' acidity because it influences the duration and environmental conditions in which C1, C2, C7, and C8 are elaborated.	C3 is triggered by soil temperature increase in spring (NPE*)	**Soil temperature increase** in spring (See above "Temperature accumulation")
C4 - Harvest dates	C4 determines field-side fruits' acidity because it interfers with the process of acidity decrease (C1). In Corsica, Harvest is usually done through 2 to 4 stages.	C4 and C5 depend on sociotechnical determinants (e.g. market demand), but also on the percentage and nature of colored fruits at a given moment (PS)	**Percentage and nature of colored fruits** at a given moment (PS*) are driven by coloring speed (C6)
C5 - Quantity and types of fruits removed at each harvest stage	C5 determines field-side fruits' acidity because fruits from one parcel vary a lot in acidity - mainly according to their specific size (see C7) and degree of ripening (see C1) - , while only a fraction of the available fruits are harvested at each stage. C5 has also effects on the acidity of the fruits harvested at the next stage.		
C6 - Coloring date	C6 determines field-side fruits' acidity because it is a driver of harvest date (C4), although decorrelated from the process of acidity decrease (C1). In practice, coloring date often constitutes a limiting factor to the harvest start.	C6 is accelerated by decrease in orchard temperatures, increase in day-night range of temperatures (NPE*), and abundant nitrogen and potassium nutrition during ripening period (PS*).	**Orchard temperatures** (See above "Temperature accumulation") **Nitrogen and potassium nutrition** (See above "Mineral nutrition")
C7 - Size distribution of fruits	C7 determines field-side fruits' acidity because each plot shows a large range of fruit sizes, while large-sized fruits are generally less acid than small fruits. Acid citric content of fruits seems to be diluted as fruit size increases.	C7 is driven by accumulation of temperatures above 13°C (NPE*), and by carbon, mineral, and water nutrition during the filling period (PS*). C7 is also driven by flowering quality, by the number of fruits per tree (see C8) and by nature of fruit-bearing shouts (PS*)	**Flowering quality** is driven by the nature of flower-bearing shoots (diameter and length) (PS*), by pruning (AP*). **Nature of fruit-bearing shouts** result from nature of flower-bearing shoots. **Carbon nutrition** is driven by the relationship between total leaf surface and number of fruits during filling stage, which depends on **mineral and water nutrition** and **temperature accumulation** (see above).
C8 - Number of fruits per tree	C7 determines field-side fruits' acidity because it influences size distributuon of fruits (C7) and acidity level of each fruit before maturation (C2).	C8 is driven by flowering intensity and physiological fall (PS*).	**Flowering intensity** reflects flower induction, which is driven by orchard low temperature (NPE*) and nutritional stress (PS*) during ripening. **Orchard low temperature** (See above "Temperature accumulation"). **Nutritional stress** during ripening results from mineral nutrition (See above). **Physiological fall** is driven by mineral nutrition during flowering.

The model as an "intermediary object"

The use of such a crop model to understand variability of agronomical variable or to orientate field observation is not new. Nor is the analytical distinction we made between various components and 5 compartments of acidity elaboration. What is new is the fact of using such representations as a mediating tool between the research team and his partners. In this part, we show that the model acted as an "intermediary object", enabling mutual understanding and representations convergence between opposed epistemological postures. To do so, we considered the acidity model as an "intermediary object" carrying embedded rules, which acted as a frame enabling and constraining perceptions, interactions and inputs during the participatory construction (Figure 2).

Figure 2: The acidity model as an "intermediary object"



The model structured interactions between actors, researchers, and farm survey

We can say that two rules are embedded in the model's structure, and have acted together as a normative framework structuring dialogue between actors, researchers, and experimental device. The first rule derives from the compartmental structure of the model (that is to say the analytical distinction between the 5 compartments of climate, permanent environment, non-permanent environment, plant status, and agricultural practices). The second rules stems from the choice of dividing the whole process of fruit acidity elaboration into a limited number of "components" (components are semi-independent processes observable at a specific period in a particular compartment of the cropping system). We show below that these 2 rules have been playing together, by structuring the capitalization of heterogeneous information, the co-conception of an empirical validation device, and the successive model refinement in the light of results from field observation.

Models' structure has facilitated the incorporation of heterogeneous pieces of information into a coherent analytical framework. First, actors' inputs were varying from theoretical knowledge on agronomical or physiological mechanisms to account of empirical experiences and isolated observations. Actors' contributions were regarded a priori as valid, provided that the group reached a consensus. Using model's systemic frame, researchers attributed each mentioned mechanism to an acidity component (or to an elements directly or indirectly determining the elaboration of one component). This was especially useful after the first workshop, when we built the first generation model by reviewing consistent quantity of diversified and rambling data. Then, the component analysis helped actors to overcome complexity (at the beginning of the process researchers were confronted to remarks such as: "everything is inextricably connected"), and successively focus actors' attention on well identified processes. Thus, actors were asked to explain which elements of the cropping system were involved in the elaboration of each identified components of fruit acidity. This approach was used to design the second generation model: during the second workshop and bilateral meetings, where actors could easily refine the model because component analysis channeled their inputs and perceptions. Third, models' compartmental structure was helpful because it helped researchers in the overcoming of analytical shortcuts or confusions. Fourth, the rules embedded in the model's structure enabled the objectivation of actors' inputs when "colored" by their ontological postures. For instance, it was a mediating tool to encourage actors to translate prescriptions into objective processes.

The models' structure has not only facilitated the incorporation of heterogeneous data. It has also directly driven the participative selection of the field observations to be implemented. Acidity components were used so as to identify periods and kind of field observations, and compartments were used to identify where to implement observations. For instance, in the case of C1 (acidity draw down rate during ripening), the representation given by the model encouraged researchers to monitor evolution of fruit quality (sugar, citric acid concentration, and juice percentage) for each fruit size on the 21 plots of the farm network, from 1^{rst} October to early January. This was combined with other field observation such as meteorological conditions (weather stations), water nutrition state (delta C13 analysis of fruits sampled in October and December, completed with calculation of full water balance), soil permeability, slope, deepness of rootlets, grass cover, and irrigation regimes.

Contribution of the model to the convergence of actors' representations

The model's infrastructure also allowed researchers to put together different representations of fruit acidity into a single coherent framework. In fact, actors in the participatory device had all significant knowledge on fruit acidity, but this knowledge was always somehow biased by their specific institutional pattern (e.g. epistemological posture, paradigms, cognitive framework…). In this part, we show how the model could act as an "intermediary object", helping mutual understanding between actors, and representations convergence.

Each actors' group introduced in part 3.1, was characterized by patterns of institutions which shape awareness and interpretation of reality, and coordinate in return actors' perception of and knowledge on acidity determinism (**Table 3**). To build this analysis, we used the distinction between regulative rules, normative rules, and cognitive rules introduced in part 1.5 of this paper. To simplify, we found that the participative device opposed actors with reductionists and holists epistemological posture. On the one hand, reductionists envisaged fruit acidity elaboration at the tree level, considered "environment" as a black box, and couldn't upscale analysis at the cropping system level. On the other hand, holists believed that fruit acidity resulted from a wide and inextricable range of inter-linked factors, but incapable of grading factors' relative importance.

During workshops and bilateral meetings, the model acted as an "intermediary object", helping dialogue and mutual understanding between reductionists and holists. In fact, this is again the 2 rules embedded in the model (compartmental structure and component analysis) which have allowed putting these different epistemological postures together. Reductionists, who were focused on the tree level and on the interactions between genotype and the black-box of environment, could bring significant inputs by identifying some physiological mechanisms involved in fruit acidity elaboration (mainly C1, C2, C6, C7, and C8 located in physiological status compartment). In other worlds, reductionists were the one identifying the first acidity components. Holists, who had a systemic representation of agro-systems, tried to mobilize reductionists' inputs and upscale the analysis at the cropping system level. Thus, holists could explain to what extent each single components identified by reductionists could be driven by interacting climate, permanent environment, and non permanent environment, and agricultural practices. At the conclusion of the first years' participative process, we noticed a beginning of convergence between actors' representations on fruit acidity determinism. At the end of third workshop, it appeared clearly to everybody that fruit acidity was the result of a limited number of semi-independent processes (the acidity "components"), each observable at a specific period. Although at this stage, precise effect of the various cropping systems elements on the construction of acidity components was unclear, it seemed possible to grade it through a farm survey.

Table 3: Attempt to analyze how institutions coordinate actors' perception of Clementine acidity

Actors type	Regulative institutions	Normative institutions	Cognitive institutions	Understanding of acidity
Farmers	Market structure encourages farmers to focus on high calibers. Despite PGI specification, low acidity levels in fruits do not limit market access.	Caliber and agronomical yield as professional excellence criterions, putting internal quality criterions apart from knowledge accumulation and technical choice construction	Belief that genetics is the main way of controlling fruit quality. Daily routines of orchard observation leading farmers to qualify each single plot according to its caliber, yield, and fruits taste.	No idea on how agricultural practices determine fruit acidity. Rootstock, variety, and "plot effect" as the main fruit acidity drivers. Fruit acidity results from the year's meteorological condition.
Technicians, agronomists, and citrus consultant	European legislation encourages technicians and agronomists to focus their attention and efforts on phytosanitary pressure reduction.	Most agricultural practices involved in acidity construction are routinised, leading technicians and agronomists to focus on phytosanitary issues.	**Holistic epistemological posture** leading to consider the complex interactions between soil, plant, climate and practices in fruit quality construction.	Fruit acidity results from a wide range of interlinked factors.
R&D agents	Research programs and funding focused on varietal innovation and genotype x environment interactions. Clear disciplinary boundaries leading to reductionist posture	Available genetic diversity as a starting point for any R&D programs Varietal innovation as a recognized way of improving cultivated citrus.	**Reductionist epistemological posture**: plant phenotype results from interactions between genotype and the black-box of plant environment.	Fruit acidity is a physiological process resulting from interactions between genotype and plant environment. On-tree variability of fruit quality is the main level of analysis.

Discussion and conclusion

In the purpose of strengthening localized agri-food systems, there is room for innovative participatory research devices and tools able to emphasize and maintain products typicity through qualification processes. This paper reported an on-going participatory initiative designed by researchers to better understanding the variability of Corsican Clementine acidity, an important typicity attribute of this terroir product. The collaborative research included the co-conception of a heuristic acidity model, the use of the model to design an empirical validation method called Regional Agronomical Diagnosis (RAD). The acidity model took the form of a set of hypotheses regarding acidity components, their interactions throughout the tree physiological cycle, as well as the various factors influencing the variability of each component.

At the Corsican level, the model opens up perspectives for researchers and stakeholders. It could be used in further participatory research to design innovative "acidity oriented" cropping systems in adaptation to emerging challenges such as climate change, new varieties, or increasing competition of the international market of Clementine. Such technical references could feed the qualification process by allowing the definition of the practiced involved in fruit acidity rather than limiting the PGI specification to product-quality objectives. Apart from the model itself, we could identify other outputs from the participative research process. Although the challenge of uncontrolled fruit acidity was pending, it had not been collectively formulated before the research starts, leading actors to "*stick their head in the sand*". The participatory research process contributed to the shared recognition that a better agronomical control of fruit acidity is needed (and probably possible) in order to face climate change and to facilitate adoption of a quality label more demanding than the PGI. In other words, the participative process led to a beginning of "construction of the acidity problem" as a medium term challenge for the Corsican basin. More generally, our methodological approach could be used by researchers to strengthen other origin based qualification processes through a better understanding of the complex interactions between, place, people and products.

The effectiveness of our model may be assessed according to 2 criterions, the first one being the ability of the model to act as an intermediary object enabling local knowledge mobilization. We demonstrated that the rules embedded in the model could structure interactions between actors, researchers, and experimental device, channel actors' inputs, and enable representations convergence between opposed epistemological postures. The second effectiveness criterion would be the predictive capacity of the final model. At that point, we couldn't answer yet because the provisional model is still under construction, and may be subjected to other iterative refinements. If the model appeared to be predictive, it would suggest that in localized agri food systems, local knowledge are crucial resources which can be channeled by researchers by using intermediary objects as mediating tools in the perspective of addressing complex scientific problems.

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