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Reduced Meat Consumption: from Multicriteria Argument Modeling to Agent-Based Social Simulation

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35 choices towards vegetarian diets; (2) an agent-based simulation of the social diffusion of opinions
36 and practices concerning meat consumption is then introduced. The purpose of this simulation is to
37 capture the balance of vegetarian vs. meat food diets. It contributes to modeling consumer choices
38 by exploring the balance between individual values and external influences such as social pressure,
39 communication campaigns and sanitary, environmental or ethical crises.

40

41 **Keywords:** sustainable food systems; agent-based modeling; argumentation systems; food diet;
42 consumer choice criteria; animal food product.

43

44 **Short title:** Reduced Meat Consumption Modeling and Simulation

45

46 **1. Introduction**

47 The first nutrition transition involved the increase of sugar, fat, meat and processed products in
48 human diets (Popkin, 1993) and is the dominant nutritional model today. Vranken (2014) identified a
49 second nutrition transition that is occurring in the most developed countries where meat
50 consumption is currently decreasing. The transition towards the reduction of meat consumption
51 covers a wide variety of practices ranging from occasional vegetarianism to veganism (also called
52 “strict vegetarian”) (Bearsworth & Kiel, 1991). The rationale for such a transition mainly implies
53 ethical and health concerns (Jabs et al., 1998), but the environmental impact of meat consumption is
54 also highlighted to a lesser degree (Ruby, 2012). McDonald (2000) conducted individual interviews
55 with vegans and found that their nutrition transition depended on a catalytic experience that
56 oriented individuals towards information acquisition and ultimately led to a decision to change diets.
57 However, the information that led to the decision is not precisely known among vegetarians. Under
58 what conditions are we likely to observe the emergence of a second transition? This paper aims to
59 understand and simulate the impact of different types of messages on the choice to change food
60 diets at the individual level, and the impact of the diffusion of opinions at the collective level.

61 As a first step, we present a methodology to explore the main arguments and the relationships
62 between them that transitioning individuals may face. The approach is based on the principles of
63 argumentation networks, an artificial intelligence model based on the construction and evaluation of
64 interacting arguments. Most of the existing models are grounded in the abstract argumentation
65 framework proposed in Dung (1995). In this framework, an argumentation system is defined by a set
66 of arguments A , and an attack relation between arguments R . Sets of arguments that “make sense”
67 together are then computed and are referred to as extensions. In a subsequent study (Thomopoulos,

68 2018), various indicators were defined to analyze argumentation systems by highlighting consensual
69 and non-consensual aspects of the issue debated.

70 As a second step, an agent-based simulation is proposed. Following the theoretical approach of Xie et
71 al. (2011), argument networks may take advantage of being used together with agent-based
72 modeling (ABM) to explore the emergent establishment of new social norms in the specific case of
73 vegetarianism. Such a model can help understand the conditions under which such arguments could
74 circulate in a population and favor the adoption of a vegetarian diet.

75 Agent-based models offer a way of taking inter-individual heterogeneity, social interaction and
76 interdependence, adaptation, and decision-making into account at different levels. In the
77 environmental sciences, these models have proved to be a way to capture complex characteristics of
78 socio-ecological systems (Epstein & Axtell, 1996; Berger, 2001; Parker et al., 2003; Mathieus et al.,
79 2007; Rammel et al., 2007; An, 2012; Filatova et al., 2013). In this family of ABM studies, ecology and
80 geography are dominant (Grimm, 1999; Parker et al., 2003; Verburg & Veldkamp, 2005; Castella et
81 al., 2005; Railsback et al., 2006). However, the social sciences are also present in ABM approaches to
82 assess and explain the complexity of human decision-making processes and behaviors (Schelling,
83 1971; Epstein & Axtell, 1996; Simon, 1997; Janssen et al., 2000; Janssen & Ostrom, 2006; Robinson et
84 al., 2007).

85 In the food sciences, historically based on process-oriented studies, ABMs are absent from the range
86 of models used to approach food quality and, as a more recent concern, food sustainability. Recent
87 studies related to multi-agent systems applied to the agri-food sector are those based on the
88 argumentation theory (Bourguet et al., 2013; Thomopoulos et al., 2015; Thomopoulos & Paturel,
89 2017). However, social issues are deeply involved in food system sustainability. Consumer demand,
90 environmental awareness, willingness to pay, acceptability of products and the transmission of new
91 food habits are all key factors to analyze the food system. Consequently, there is an urgent need and
92 a real challenge to take food-related social behaviors into account and to integrate them into food
93 policy analysis.

94 A previous approach for combining argumentation and simulation for decision support in food
95 systems was proposed in Thomopoulos et al. (2017). The simulation model considered in that study
96 was systems dynamics. In this paper, an ABM simulation of the social diffusion of opinions and
97 practices concerning meat consumption is proposed. It aims to capture the balance of vegetarian vs.
98 meat food diets. More specifically, we aim to understand the balance between individual values and
99 external influences such as social pressure, communication campaigns and sanitary, environmental
100 or ethical crises in the decision-making of individuals with regard to their food diet.

101

102 **2. Materials and Methods**

103

104 **2.1. Argumentation Formalism**

105 In order to model arguments involved in vegetarian transitions, we used an abstract argumentation
106 approach (Dung, 1995; Rahwan & Simari, 2009; Thomopoulos, 2018). Let us recall that an
107 argumentation system is usually represented as an oriented graph where nodes are arguments and
108 edges are attack relations between arguments (Figure 1). Considering Dung’s seminal work on
109 argumentation (1995), an argument and the attack relation are abstract and can be instantiated and
110 defined in different ways in different contexts (Walton, 2009). Dung himself stated: “an argument is
111 an abstract entity whose role is solely determined by its relations to other arguments. No special
112 attention is paid to the internal structure of the arguments.” For example, an argument can be a set
113 of statements composed of a conclusion and at least one premise, linked by an inference or a logical
114 relationship. Attacking an argument can be achieved in different ways: (1) by raising doubts about its
115 acceptability through critical questions; (2) by questioning its premises; (3) by suggesting that the
116 premises are not relevant to the conclusion; or (4) by presenting an argument with an opposing
117 conclusion. In all these cases, an attack relation is said to exist.

118 Even though Dung’s framework is theoretically sound, it is not straightforward enough to be applied
119 to real-life situations. Indeed, one of the initial difficulties is how to define an argument in order to
120 properly reflect stakeholders’ statements in a debate. Unfortunately, there is still no general model
121 that can be used to formalize a natural argument (i.e., an argument stated by a stakeholder during a
122 discussion in natural language) and input in an abstract argumentation framework in a real decision-
123 making context. Quoting Baroni & Giacomin (2009): “While the word ‘argument’ may recall several
124 intuitive meanings, like the ones of ‘line of reasoning leading from some premise to a conclusion’ or
125 of ‘utterance in a dispute’, abstract argument systems are not (even implicitly or indirectly) bound to
126 any of them: an abstract argument is not assumed to have any specific structure but, roughly
127 speaking, an argument is anything that may attack or be attacked by another argument.” Indeed, the
128 structure of an abstract argument does not correspond to the intuitive understanding of what an
129 argument is. Moreover, the notion of “attack between arguments” does not have a natural and
130 direct correspondence to practical expressions used by stakeholders when debating. Finally,
131 representing arguments as an oriented graph can be a difficult task for stakeholders: when the
132 number of arguments and/or attacks is large, the graph becomes illegible and difficult to interpret by
133 the stakeholders. For all these reasons, the ways that arguments and attacks are identified and
134 modeled is part of the project contributions. They are thus presented in Section 3.

135

136 2.1.1. *The arguments*

137 In our project, we need to find a practical way of defining arguments that are used in the process of
138 decision-making. In such a context, arguments can be intuitively thought of as being statements to
139 support, contradict or explain opinions or decisions (Amgoud & Prade, 2009). More precisely, in
140 decisional argumentation frameworks (Ouerdane et al., 2010), the argument definition is enriched
141 with additional features, namely the decision (also referred to as ‘action’, ‘option’ or ‘alternative’)
142 and the goal (also referred to as ‘target’). In other studies, arguments are also associated with
143 specific actors. An application of a decision-oriented argumentation framework to a real-life problem
144 concerning food policy can be found in Bourguet et al. (2013), where a recommendation regarding
145 the provision of whole-grain bread was analyzed a posteriori. In this case, each argument is
146 associated with the action it supports.

147

148 2.1.2. *The attack relation*

149 Now, let us consider the attack relation. In structured argumentation (i.e., logic-based argumentation
150 frameworks where arguments are obtained as instantiations over an inconsistent knowledge base)
151 three kinds of attacks have been defined: undercut, rebut and undermine (Besnard & Hunter, 2008).
152 The intuition of these attack relations is either to counter the premise of the opposing argument
153 (‘undercut’), the conclusion (‘rebut’) or to attack the logical steps that allowed the inference
154 between the argument’s premise and conclusion (‘undermine’). In abstract argumentation, the set of
155 attacks is simply considered as provided a priori. Another possibility that can be considered is to
156 enhance the argumentation framework with a set of preferences expressed, for instance, as weights
157 representing uncertainty. In our project, we needed to choose a practical way to define the attack
158 relation.

159

160 **2.2. Agent-Based Modeling**

161 Agent-based models are computational models used to simulate the actions and interactions of
162 individual or collective autonomous agents in order to assess their effects on the system as a whole.
163 They attempt to reproduce and predict the emergence of complex phenomena induced from the
164 micro-scale to the macro-scale. Their principle is that simple local behavioral rules generate complex
165 global behavior. An overview of their early history can be found in Samuelson (2000), and more
166 recent developments in Samuelson & Macal (2006).

167 The model introduced was built and run on two different agent-based modeling and simulation
168 platforms, namely CORMAS and GAMA (Taillandier et al., 2018). The CORMAS platform
169 (<http://cormas.cirad.fr/>) was specifically developed by CIRAD – the French international cooperation

170 organization for agricultural research in the global South – to simulate natural resource
171 management, and is oriented towards the representation of interactions between stakeholders
172 about resource use. In CORMAS, entities are categorized into three types: spatial entities describing
173 the space at different aggregation levels, passive entities that are objects that can be manipulated by
174 social agents, and social entities that can make decisions, move, and interact with other agents. The
175 GAMA platform (<http://gama-platform.org>) was developed by a consortium of research teams using
176 the JAVA language. It is generalist in its application domains and is particularly well-suited for
177 connection with geographical information system data and visualization.

178

179 **3. Results and Discussion**

180

181 **3.1. Argumentation Results**

182

183 *3.1.1. Contributions to Modeling Arguments and Attacks*

184 We introduce the specification of an argument as a tuple $a = (I;T;S;R;C;A;Is;Ts)$ where:

185 – I is the identifier of the argument;

186 – T is the type of the argument (with values in favor of, denoted by '+', or against, denoted by '-', the
187 vegetarian option);

188 – S is the statement of the argument, i.e., its conclusion;

189 – R is the rationale underlying the argument, i.e., its hypothesis;

190 – C is the criterion on which the argument relies;

191 – A is the actor who proposes the argument;

192 – Is is the information source containing the argument;

193 – Ts is the type of source the argument comes from.

194 For any argument a , we denote by $I(a)$, $T(a)$, $S(a)$, $R(a)$, $C(a)$, $A(a)$, $Is(a)$, $Ts(a)$ the identifier, the type,
195 the statement, the rationale, the criterion, the actor, the information source and the information
196 type of argument a , respectively.

197 Considering the reality of stakeholders' debates and our model to formalize arguments, we chose to
198 model the attack relation in the following way. Attacking an argument a is achieved by: (1) explicitly
199 raising doubts about its acceptability by expressing a counter-argument citing a or the information
200 source containing a ; (2) implicitly raising doubts about its acceptability by expressing a counter-
201 argument contradicting a through undercut, rebut or undermine. Formally, we consider the following
202 attack relation:

203 Let a and b be two arguments. We say that a attacks b if and only if the following two conditions are
204 satisfied:

205 (1) $T(a) \neq T(b)$;

206 (2) $\{R(a), S(a)\} \Rightarrow \text{not } \{R(b), S(b)\}$.

207 The first condition expresses the fact that one of the arguments a and b is in favor and the other
208 against the vegetarian option. The second condition expresses the inconsistency of a and b , i.e., if the
209 hypothesis and the conclusion of argument a are assumed to be true, then the hypothesis of b or the
210 conclusion of b , or both, do not stand.

211

212 3.1.2. Exploring the Literature

213 Following the above formalism, we extracted arguments in favor or not of reducing animal product
214 consumption. Our sources of arguments are newspapers, gray literature and the top ten Google
215 search words (“vegetarian diet”; “vegan diet”; “vegetalism argument”). The latter inquiry was added
216 to the pool of popular scientific papers, WebMedia articles and blog posts. We thoroughly read each
217 source and extracted all of the arguments as expressed by their authors. For each argument, we
218 attributed a criterion (“Nutritional”; “Economic”; “Environmental”; “Anthropological”; “Ethical”;
219 “Health” or “Social”) and noted the source expressing this argument (“Journalist”; “Scientist”,
220 “Philosopher”; “Blogger”, etc.). We consequently obtained 114 arguments.

221 Table 1 displays a sample of the set of arguments considered in our case study. Each argument was
222 first formalized by an identification number, whether it is in favor or not of meat reduction diets (+/-
223), its main statement and rationale such as: “Vegan diet is related to vitamin B12 deficiency”
224 (Statement) since “plants do not contain vitamin B12” (Rationale). Other information (Actor,
225 Information source & Type of source) characterizes the origin of the argument. Based on this first
226 step, we then formalized attacks between them. An attack occurs when an argument contradicts
227 another one. For example, the argument “1” quoted above is contradicted by the following argument
228 “28 - Properly planned vegetarian or vegan diets fit all stages of life” since “Nutrient needs are
229 satisfied and growth is normal.” When these arguments are graphically formalized, each one is
230 represented as a node, and an attack is a vertex connecting both arguments where the arrow points
231 to the direction of the attack. In our case study, we identified 155 attacks connecting 55 arguments
232 out of a total of 114.

233

234 3.1.3. Graphical representation of the argument network

235 In order to make a graphical representation of the argument network, we used the visualization
236 program Yed Graph Editor (version 3.17.1). We chose to represent only arguments that are

237 connected with at least one attack. Hence, 55 arguments were kept and 59 were rejected. The result
238 is displayed in Figure 2. Each number corresponds to one argument expressed by one source.
239 Arguments are grouped in dashed lines according to the criterion they are based on, which is
240 indicated in the legends (Nutritional, Ethical, etc.). Each argument node received a specific color
241 according to its source (e.g., pink for argument 1 from the newspaper “Le Canard Enchaîné”, No. 144,
242 published in July 2017, blue for arguments 2 to 16 from the Valorial competitiveness cluster’s
243 presentation, etc.). For visualization purposes, we merged identical arguments in the same node
244 when they were repeated and came from the same source.

245

246 **3.2. Agent-Based Simulation Results**

247 *3.2.1. Conceptual model*

248 Scenario Description

249 The system modeled is a country consisting of a population of N citizens. Each citizen is characterized
250 by: (i) a constant level of need for quality regarding food (environmental preservation, ethics, health,
251 taste, etc.); (ii) a variable level of perception of meat products corresponding to these criteria.
252 Depending on these two levels, citizens have a behavior regarding their food diet - either meat
253 consumers if their perception exceeds their needs, or vegetarian if their needs exceed their
254 perception. This principle is represented in Figure 3. Moreover, each citizen has some resistance to
255 change, represented by the resistance rate.

256 Within this system, each citizen communicates with his/her direct neighbors and may then change
257 his/her perception of meat consumption and, consequently, his/her diet. Citizens are also influenced
258 by advertising campaigns that target every citizen and tend to increase meat product perceptions in
259 the whole country. Finally, crises break out with a given frequency. These represent, in particular,
260 sanitary crises and, more generally, ethical or environmental crises. All of the citizens receive the
261 information, all the more since they are spatially close to the crisis event. Their perception of meat
262 products may be impacted.

263 Initial parameters subject to stochasticity include the distribution of need and perception levels in
264 the population with respect to some initial proportions of vegetarians and meat consumers. The
265 output parameter observed is the evolution of food diets over time.

266

267 Working Hypotheses

268 The ABM developed was based on the following assumptions:

- 269 • A cognitive theory of food perceptions and needs. This is where the ABM is related to arguments
270 in favor or not of a diet, and where the importance attached to the criteria underlying arguments

271 for a given diet is expressed here as a level of needs. The failure of a food diet to be perceived as
272 being consistent with these needs leads to a behavioral change in the ABM, which cannot be
273 captured by the argumentation system alone.

274 In Schlüter et al. (2017), six categories of human decision-making behaviors in socio-ecological
275 systems are described. In the present paper, we drew on the “habitual behavior”, described by
276 the following characteristics (quoting Schlüter et al. (2017)):

- 277 - “Behavior is initially deliberate and goal-directed;
- 278 - if new behavior is rewarded, the chances increase that it will be repeated;
- 279 - repeatedly obtaining satisfactory rewards reinforces the behavior;
- 280 - the selection of behavior will be automatic as long as needs are satisfied;
- 281 - the actor will stop automatic behavior and deliberate about alternative behaviors if need
282 satisfaction drops below a critical level;
- 283 - if the reward devalues or disappears, habitual behavior persists at first, but will go
284 extinct after longer absence of reward.”

285 • Three triggers for vegetarian/meat product demand: (i) occurrence of sanitary, environmental
286 and ethical crises; (ii) neighborhood effect; (iii) advertising campaigns. The influences of these
287 triggers are assumed to follow the opinion diffusion model (Deffuant et al., 2002). An opinion (in
288 this case, a perception of meat products) is represented by a numerical float value between 0.0
289 and 1.0, initialized with a random value that is less than needs for vegetarians, and greater than
290 needs for meat consumers. At each step, agents consult their neighbors and update their
291 opinions as follows. When agent x consults his/her n neighbors y_i ($i \in [1; n]$), his/her new opinion
292 will become:

$$293 \text{opinion}_x(t+1) = \text{resistanceRate} * \text{opinion}_x(t) + (1 - \text{resistanceRate}) * \text{mean}_i(\text{opinion}_{y_i}(t)).$$

294 The resistance rate is a parameter of the simulation, i.e., a number in [0.0, 1.0].

295

296 3.2.2. Simulations Results

297 Figure 4 displays a running simulation of the model developed, implemented in the CORMAS
298 platform. The left part shows consumer perceptions of meat products (the darker, the higher). The
299 right side displays the resulting food diets: green for vegetarians, red for meat consumers. The yellow
300 stars depict the occurrence of a crisis that tends to decrease people’s perceptions of meat products,
301 all the more since the crisis localization is close. The pink circles depict the occurrence of an
302 advertising campaign that tends to increase people’s perceptions of meat products. Although
303 localized (in order to visualize them), advertising campaigns are nationwide and impact every citizen,
304 as already mentioned.

305 Figure 5 shows a running simulation of the same model, implemented in the GAMA platform. As in
306 CORMAS, food diets are represented in green for vegetarians and in red for meat consumers.
307 Perceptions of meat products are represented by the sizes of the circles (the larger the circle, the
308 higher the perception). The left part of the screen makes it possible to display and easily modify
309 simulation parameters.

310 Each step has been calibrated to correspond to about one month, so that the whole simulation
311 corresponds to approximately 15 to 20 years.

312

313 3.2.3. Sensitivity Analysis

314 Sensitivity analysis raw results are given in Figures 6 to 9 and further commented in Section 3.3. The
315 parameters analyzed are, respectively:

- 316 - the ratio between the frequencies of crises and communication campaigns (Figure 6);
- 317 - the initial proportion of vegetarians (Figure 7);
- 318 - the radius of crises (Figure 7);
- 319 - the progression over time of the resistance rate, constant or adaptive (Figure 8). In the latter
320 case, the resistance rate tends to increase for individuals who have already experienced a food
321 diet change, reflecting some “no going back” effect;
- 322 - the introduction of resistance to communication campaigns (Figure 9);
- 323 - the introduction of a selective influence of neighbors, where those with perceptions closer to
324 the agent’s perception are more carefully listened to (Figure 9).

325

326 3.3. Discussion

327 Our argument network structure reveals two main elements in particular. First, it can be observed
328 that arguments about Health are by far the majority of the arguments identified. They represent 47%
329 of all of the 114 arguments identified and 63% of the arguments involved in at least one attack. As a
330 matter of comparison, ethical arguments represent only 3% of all arguments identified. Second,
331 some key arguments emerge due to their centrality. Three arguments are involved in more than four
332 attacks. The first argument, grouped under identification numbers 28, 57, 108 and 111 (the black
333 node in Figure 2), refers to a scientific paper from the American Dietetic Association stating that
334 “Properly planned vegetarian or vegan diets fit all stages of life” (Craig & Mangels, 2009). The second
335 argument, grouped under identification numbers 71 and 72, is a journalist’s statement that “No
336 study is favorable to the vegan diet”. The third argument, number 83, states that “vegan diet safety
337 is not proven”, questioning the validity of scientific studies in this regard. These arguments would

338 probably be key arguments in potential controversies about vegetarian diets due to their generality
339 and to their polarized nature on the question of such diet viability from a health perspective.

340

341 The major importance of health issues surrounding vegetarian diets is in line with findings in Ruby's
342 (2012) review of vegetarian studies. On the opposite, the importance of ethical arguments that was
343 stressed by Ruby (2012) did not appear in this modeling. This could be explained by the more
344 complex nature of ethical arguments as well as our choice of search words in Google that focused on
345 diets. However, from an ethical perspective, it seems that the health issue (whether or not
346 vegetarian diets are healthy) is central since vegetarianism may be defended from the baseline of
347 animal products not being necessary for human health (Francione & Charlton, 2013).

348

349 In this study, we built the network and proposed a structural analysis. Abstract argumentation leads
350 to further analysis and, in particular, the rejection of attacked arguments without any argument to
351 defend them. Such analyses allow for new indicators such as those that measure the degree of
352 controversy based on rejected argument ratios (Thomopoulos & Paturel, 2017; Thomopoulos, 2018),
353 which can better identify potential controversies.

354

355 The present work illustrates a promising coupling of the argumentation theory and agent-based
356 modeling. The use of ABM is complementary since it allows for the exploration of conditions under
357 which arguments could spread in a population and favor the adoption of a vegetarian diet. The way
358 arguments build public opinion and may lead to behavioral changes can be simulated by the ABM,
359 whereas this dynamic cannot be captured by the argumentation system alone. A comparison of the
360 argumentation and ABM representations that emerged from this study is proposed in Table 2.

361

362 The simulation results and, more specifically, sensitivity analysis, showed that arguments in favor of
363 meat reduction can be widely diffused in the population and that the repeatability of this result is
364 dependent on several parameters. Among them, the ratio between the frequencies of crises and
365 communication campaigns plays an important part in the stability of the results obtained over the
366 simulations (Figure 6). It is interesting to notice that the initial proportion of vegetarians has little
367 effect compared to that of the radius of crisis impact (Figure 7). Moreover, another parameter was
368 demonstrated to impact the stability of the model, namely the scalability of the resistance rate.
369 Indeed, when resistance to change increases in the case of food diet change, the results in terms of
370 the final number of vegetarians are much more homogeneous over the simulations (Figure 8). This

371 observation is confirmed in the particular cases where this enhanced resistance affects consumer
372 receptivity to communication campaigns and differently-thinking neighbors (Figure 9).

373

374 A crucial issue in argument modeling and simulation is the completeness and the robustness of the
375 information collected. Of course, such a complex issue could ever pretend to be exhaustive. So how
376 can the question of completeness be dealt with? A first possible direction is to combine different
377 types of information, in particular quantitative sources of information such as large surveys which
378 allow analyzing the representativeness of different viewpoints, and qualitative ones which allow
379 identifying nuances. In this perspective, ongoing research extends the set of arguments elicited so as
380 to include, on the one hand, quantitative results from a survey of 2,000 people questioned on their
381 current and ideally intended food habits, and data from the French National Institute of Statistics and
382 Economic Studies (INSEE) to model social networks at the level of a city; and on the other hand,
383 qualitative results from 20 biographic interviews that provide in-depth understanding of the
384 motivations, initiating events, brakes and facilitators of food diet changes on the long-term. A second
385 possible direction is to observe the evolution of the plus-value brought by new information sources
386 in time. When no more substantial novelty is brought, a fixed point is reached.

387

388 Another thorny issue is the perceived reliability of arguments and its role in opinion dynamics.
389 Indeed, the way arguments are processed can also be refined. Presently, argument perception
390 depends on the criteria addressed by the argument and on the importance of these criteria for each
391 citizen. Other factors can impact the perception of an argument, in particular, the source of the
392 argument (Pornpitakpan, 2004). Hence, messages from dubious sources can differentially impact
393 citizens' responsiveness. Various types of influencing agents can be distinguished, such as lobbies,
394 the government, companies, etc., with various strategies to diffuse arguments.

395

396 **4. Conclusions**

397 The method presented in this paper formalizes arguments and attacks around vegetarian diets using
398 an abstract argumentation approach. The argument network revealed the foremost importance of
399 health issues surrounding vegetarian diets. The centrality of some of the arguments in the network
400 allows for identification of potential key arguments and/or controversies. The importance of health
401 arguments in relation to ethical arguments should be further researched.

402

403 Argument networks take advantage of being used together with ABM to explore the emergent
404 establishment of new social norms in the case of vegetarianism. The overall research demonstrates

405 the potential of developing an ABM to predict the triggers impacting the dynamics of food habit
406 changes. Crises – sanitary, environmental and ethical – lead to the adoption of vegetarian products
407 by consumers. The above results indicate that there is the potential of extending the reach of
408 nutrition transition by acting on several parameters: counterbalance of advertising campaigns by
409 awareness campaigns, wide diffusion of awareness messages, and measures encouraging people to
410 maintain their new habits and deterring them from backing down.

411

412 An interesting issue to further investigate is how public opinion is formed in the case of crises,
413 including situations where the assumptions that the whole population is well informed and the news
414 is reliable do not hold.

415

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420

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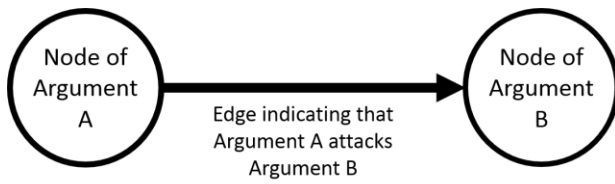
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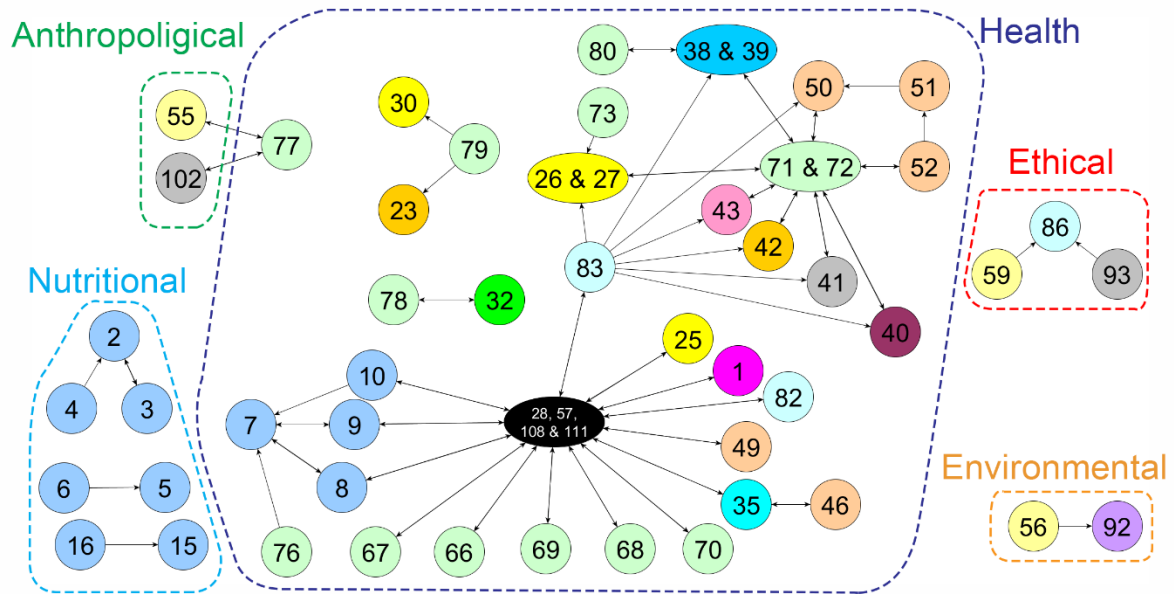
528 **Figure captions**



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530 **Fig. 1.** General graphical representation of an argumentation system.

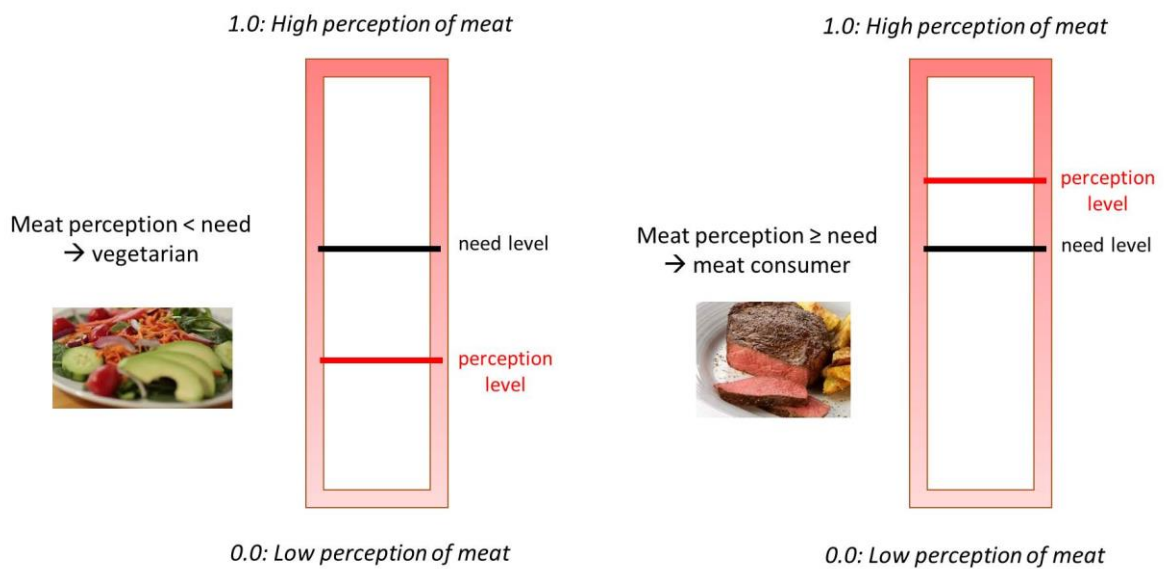
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533 **Fig. 2.** Graphical Representation of Arguments and Attacks about Reduced Meat Consumption.

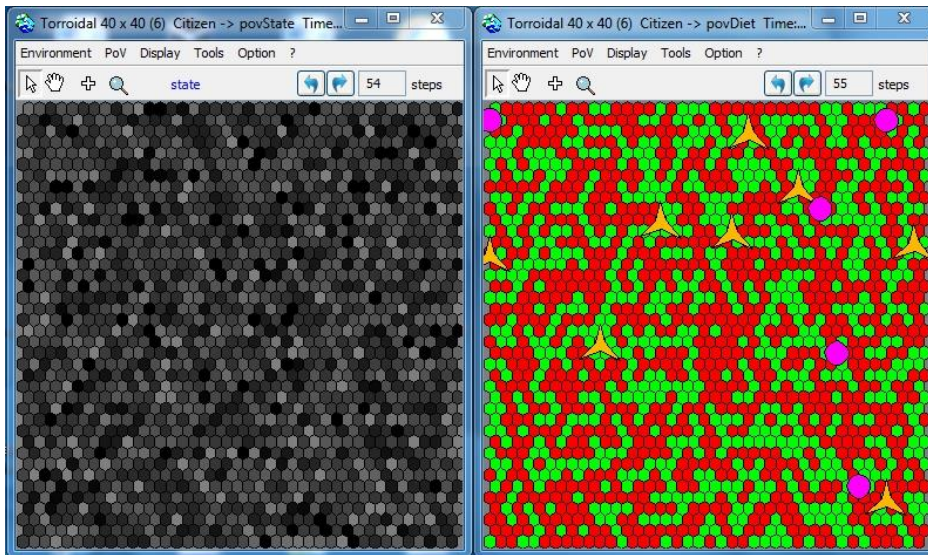
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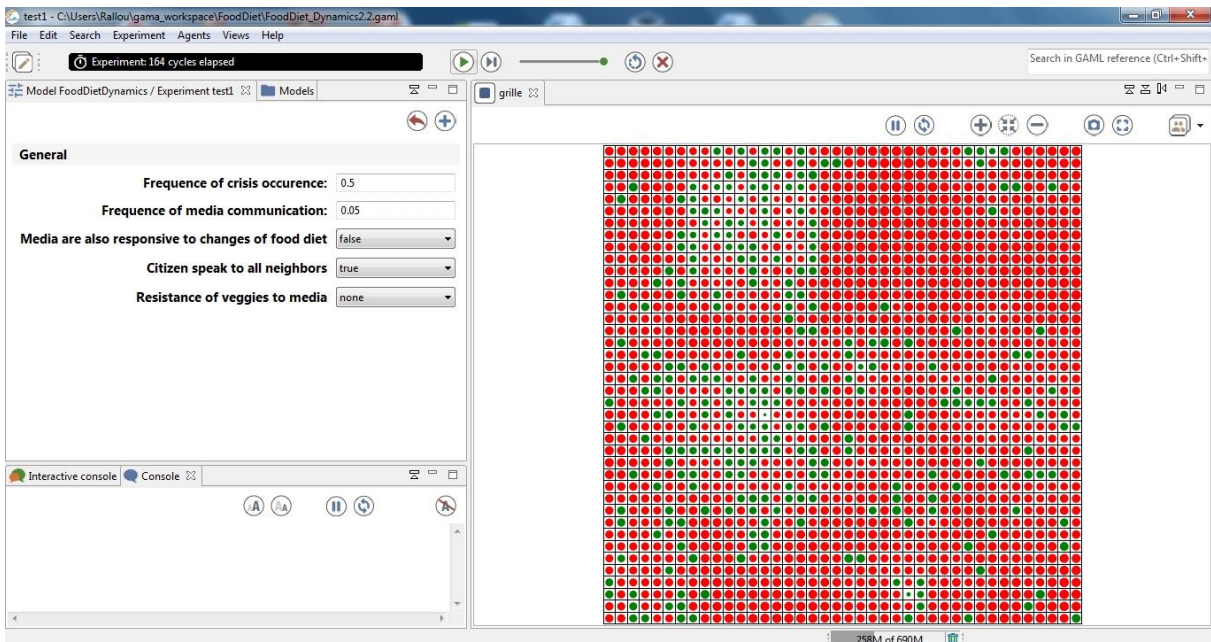
536 **Fig. 3.** Behavioral model of food diet choice.

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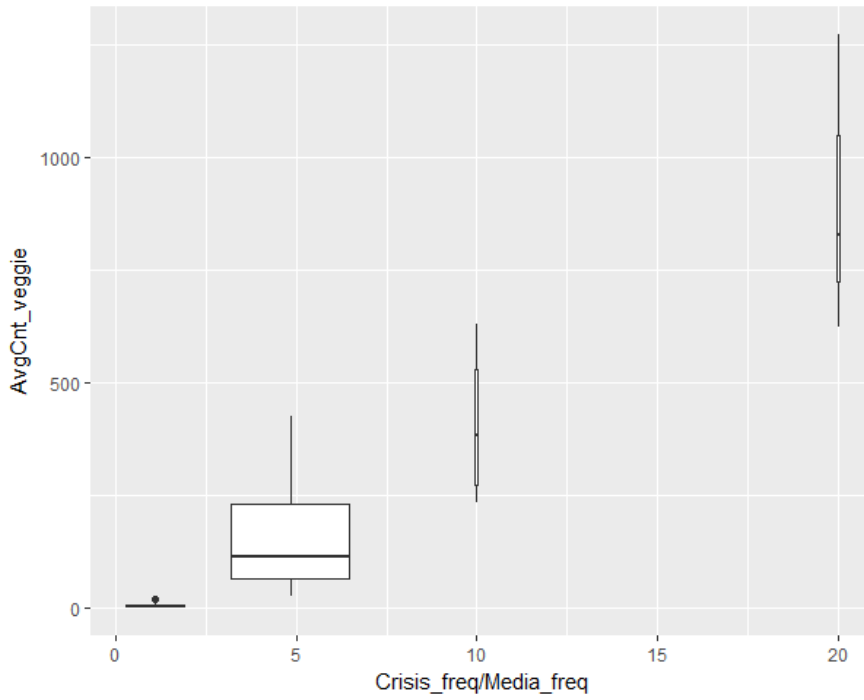
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Fig. 4. A running simulation in CORMAS.



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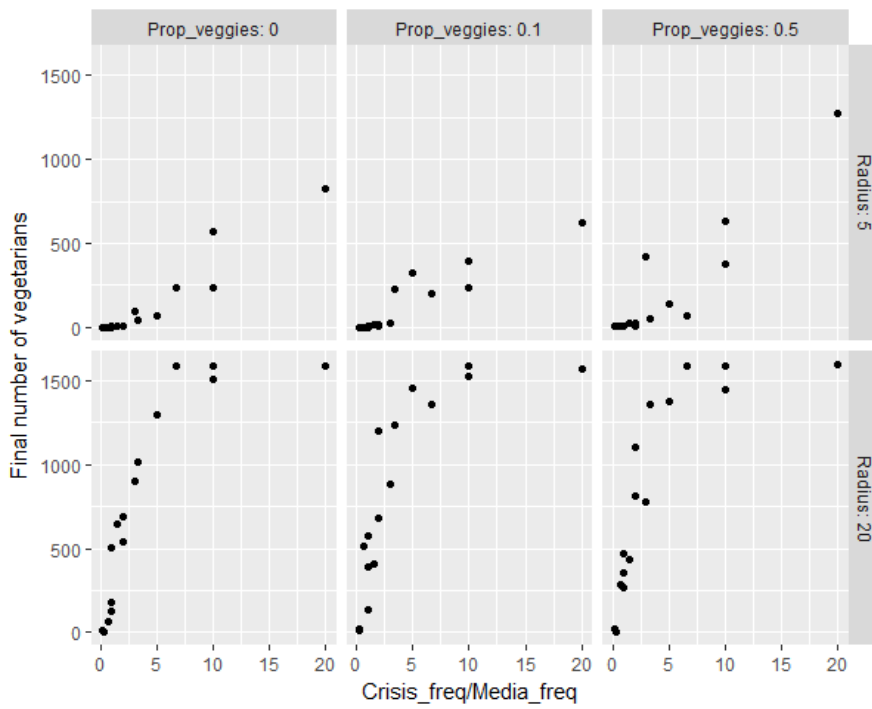
Fig. 5. A running simulation in GAMA.



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545 **Fig. 6.** Effect of the ratio between the frequency of crises and that of communication campaigns.

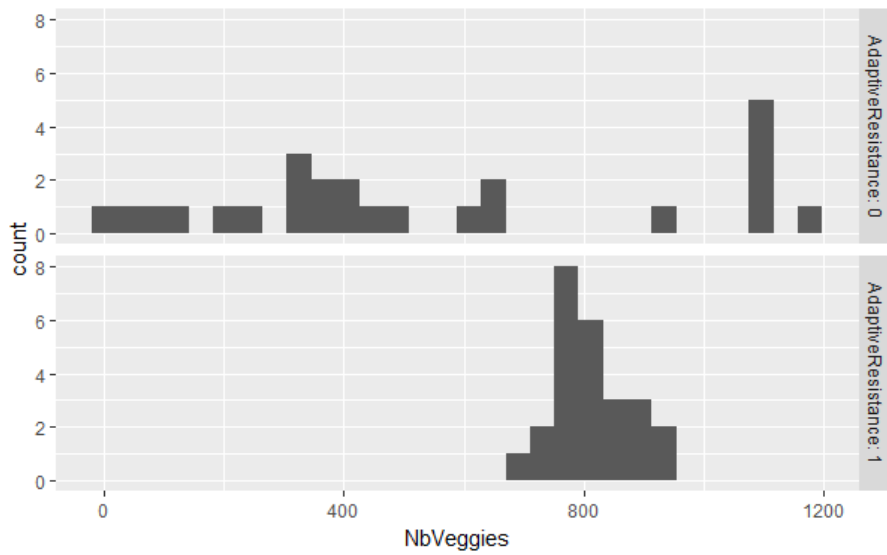
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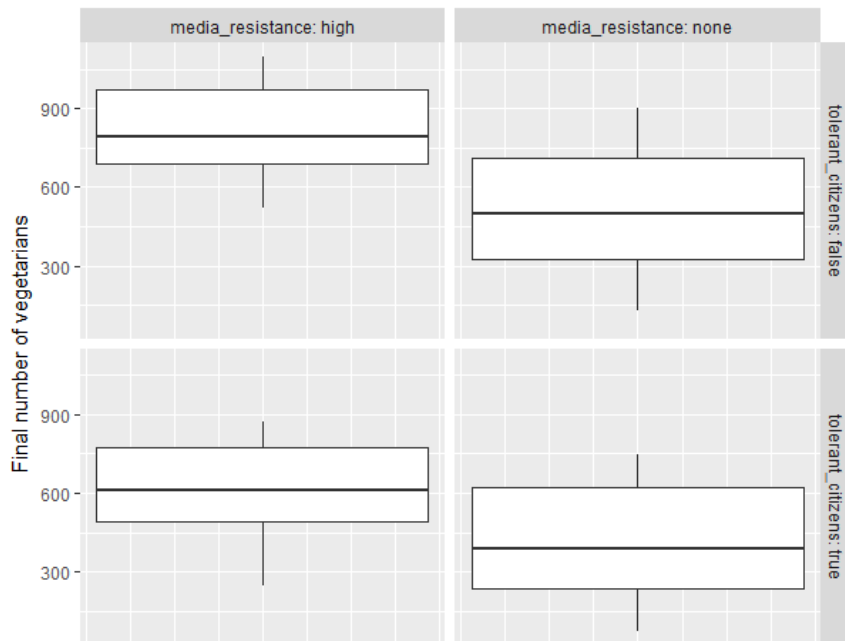
548 **Fig. 7.** Combined effects of the initial proportion of vegetarians and of the radius of crises.

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551 **Fig. 8.** Effect of the adaptive resistance rate.

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554 **Fig. 9.** Effects of resistance to communication campaigns and of the selective influence of neighbors.

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557 **Tables captions**

558 **Table 1.** Sample of Argument Tuples about Reduced Meat Consumption (I: Identification; T: Type; Is:
559 Information source; Ts: Type of source).

I	T	Statement	Rationale	Criterion	Actor	Is	Ts
1	-	Vegan diets are deficient in vitamin	Plant proteins do not contain vitamin B12	Nutritional	Journalist	Canard Enchaîné - 144 - July 2017	Newspaper

		B12					
7	+	Persons not consuming animal products do not have health issues related to proteins	Combined protein intakes ensure a balanced diet	Nutritional	Innovation cluster	Valorial	PowerPoint
15	-	Plant proteins trigger allergies	Plant-based food are more often allergenic	Nutritional	Innovation cluster	Valorial	PowerPoint
23	+	Vegetarian diets are good for health	Diabetes, cancer and coronary risks are reduced	Health	Scientists	Tilman & Clark 2014	Scientific paper
28	+	Properly planned vegan or vegetarian diets fit all stages of the life cycle	Nutrient needs are satisfied and growth is normal	Health	American Dietetic Association	Craig et al. 2009	Scientific paper
43	+	Vegan diets improve rheumatoid arthritis activity	A diet-induced fecal flora change was observed	Health	Scientists	Peltonen et al. 1997	Scientific paper
55	+	Eating meat is not in human nature	It was sometimes necessary in the past to eat meat, not today	Anthropological	Blogger pro-vegan	Blog - Eleusis and Megara	Blog post
56	+	Stopping eating animals does not mean animal extinction	Deforestation for the cultivation of animal feed provokes species extinctions	Environmental	Blogger pro-vegan	Blog - Eleusis and Megara	Blog post
57	+	Animal products are not essential to good health	B12 intakes in animal products come from B12 industry production anyway	Nutritional	Blogger pro-vegan	Blog - Eleusis and Megara	Blog post
59	+	Animals suffer when eaten, not plants	A nervous system is needed to suffer, which plants do not have.	Ethical	Blogger pro-vegan	Blog - Eleusis and Megara	Blog post
71	-	No study is favorable to the vegan diet	One good-quality study showed that the Atkins diet is better than the Ornish diet	Health	Journalist	Signs of the Times	Internet article
72	-	No study is favorable to the vegan diet	Study showing health and mortality advantages from a vegetarian and vegan diet do not show causation	Health	Journalist	Signs of the Times	Internet article
77	-	No health reason justifies avoiding animal products	The human body has been adapted to eating animal products for millions of years	Health	Journalist	Signs of the Times	Internet article
83	-	Vegan diet safety is not proven	So far, scientific studies do not have much value and especially on long-term effects.	Health	Philosopher	Huffington Post	Blog post
108	+	Animal products are useless for your health	The American Dietetic Association says so	Nutritional	Website editor	VeganFrance.fr	Web directory
111	+	There is no health issue with a balanced vegan diet	It is recognized by many governmental and non-governmental organizations. Dieticians from Canada even say it has advantages for health	Health	Philosopher	Blog – Frédéric Côté-Boudreau	Blog post

561 **Table 2.** Comparison of argumentation and ABM models in this study.

	In argumentation	In ABM
Modeling scale:	The argument	The individual
Values (regarding food diet)	Are represented as criteria of the arguments (health, etc.)	Are synthesized by a level of needs for each individual
Assessment (of food diet)	Are represented by the type (+ or -) of each argument	Are expressed by perception levels that vary over time
Influences	Arguments may attack each other and all arguments may influence public opinion	Triggers positively or negatively impact perception levels
Resulting decision	Is attached to each argument through its type. Viewpoints can be computed but currently not quantified (e.g., through proportions).	Is attached to each individual through behavior (food diet). Trends for the whole population emerge from individuals.

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