Disentangling the connections between the GMO-related food system and food and nutrition security in Europe: A concept map from a systematic literature review[1]

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Introduction

The recent food crisis of 2007/2008 brought to the light renewed concerns about the present and the future of Food and Nutrition Security (FNS[2]) all around the world. Short-term shocks (climate events, financial crisis…) intertwined with long term pressures (climate change, demographic growth, nutritional transition in emerging economies) to give a revived momentum to global and national debates about how to sustainably feed a growing population (Hertel, 2015).

The European Union has not been apart from these debates. This has been clearly reflected throughout the process of negotiation of the new Common Agricultural Policy (CAP), where food security became a prominent topic (Candel et al., 2014). Moreover, the food challenge has been tackled by the EU not only regarding internal food security, but also reconsidering the role of the EU in fighting hunger in developing countries (European Commission, 2009). This contribution to global food security has been also considered in national debates (e.g. UK, see DEFRA 2008).

In the course of these debates, the role to be played by Genetically Modified (GM) crops has been a controversial issue. Interestingly, much of the debates on GM within developed countries have revolved around its benefits or disadvantages in meeting FNS needs in the developing world (Didden et al., 2013). Yet, the potential of GM technology to overcome domestic production constraints has been also an argument utilised by pro-GM stakeholders (see for instance Ortiz et al., 2015 on the case of Spain).

The objective of this paper deals precisely with the intertwined relationships and mechanisms operating within the European GM-food system. Taking into account Ericksen's conceptualization of the food system (Ericksen, 2008) our analysis aims to identify, within the EU GM-food topic,(1) the main drivers of change that affect (2) the GM-related food system activities that, in turn, give rise to (3) food system outcomes (dimensions of food security).

For the study to be done, we developed a two-step analysis. First, we developed a systematic literature review to built a documentary basis for qualitative data analysis with computer software to identify relevant connections between the components of the GMO-related food system. Second, these components are used to construct a concept map that shows the mechanisms operating within the food system that intermediate between drivers of change affecting GMO related activities and its FNS implications. The systematisation of these mechanisms will allow to better understand the debates at play and the role of policy-drivers. This paper is a preliminary outcome of an ongoing research that aims to better understand the European debates on FNS and its current and future vulnerabilities.

The structure of the paper is as follows. Next section describes the EU policy framework that regulates GM food developments. Then, we explain the methodological steps followed in our analysis. The results and discussion section includes two concept maps obtained, together with the list of references behind each linker. Both allow to identify relevant hotspots that are discussed in-depth. Finally, we extract some concluding remarks.

[2]In this paper we adopt the concept of FNS as defined in CFS (2012): "*Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life".*

The policy framework

There is extensive evidence that European citizens/consumers are more sceptical and reluctant to Genetically Modified (GM) food than those from other regions, particularly America and Asia (Dannenberg, 2009). This can be partially explained by recent food safety incidents in Europe that have also eroded the confidence of consumers in regulatory authorities, leading to a risk-aversion approach to GMO. Nevertheless, risk alone does not fully explains the public opposition to GMO and it is also necessary to consider other important factors such as environmental concerns, socio-economics issues, lack of usefulness perception or general attitude to scientific research (e.g. Devos et al., 2008).

Although not homogeneously across European countries and regions, this general opposition manifests in public opinion surveys and is a crucial element in explaining the EU policy and legal framework regarding GMO, which is considered to be very restrictive. This framework is made up of three main legal acts concerning (i) cultivation, (ii) food and feed uses and (iii) traceability and labelling. Indeed, the EU policy regarding GMO, combines a precautionary approach that imposes a premarket authorisation for any GMO to be placed on the market and a post-market environmental monitoring for authorised GM products. Moreover, a system of traceability and mandatory labelling for GM food and coexistence measures to avoid unintended presence of GMO in conventional and organic crops are in force in order to protect consumers' choice.

The premarket authorisation procedure entails a risk assessment on the safety of the GM for the environment and human and animal health, performed by the European Food Safety Authority (EFSA) in collaboration with member states scientific bodies. Based on EFSA's opinion, the European Commission prepares a draft granting (or refusing) authorisation and submits it to member states for decision by qualified majority. However member states have never reached a qualified majority in favour or against. In this case the Commission is ultimately obliged to adopt a decision. Despite a GMO being authorised, member states can provisionally prohibit or restrict its use on their territory invoking special safeguard or emergency clauses. This should be done only if there is new evidence that the organism concerned constitute a risk to human health or the environment, however the EFSA has judged all safeguard measures taken by member states to be scientifically unfounded. The regulatory reluctance of the EU to approve GM crops and the ban on certain GM varieties already approved by EFSA has raised questions about the legislation's supposed focus on consumers, on the basis that the policies in question are arbitrary and not based on scientific assessment, but rather are driven by political expediency or protectionist purposes (Du, 2014).

The policy debate intensified recently during the negotiation process that gave rise to the recent Directive (EU) 2015/412, which allows Member States to prohibit or restrict the cultivation of GM crops in their respective territories. Similarly, the Commission has made a proposal to extend to the import of GM food and feed the solution agreed on GMO cultivation and thus allowing member states the right to restrict or prohibit the use of GM food and feed on their territory despite it being authorised at EU level (opt out).

The national governments' room for manoeuvre has led to an uneven distribution of GM crops among member states that reflects the different political positions on the issue. At present, only one crop (Bt maize MON 810) is authorised, and it is cultivated in five countries: Portugal, Romania, Slovakia, Czechia and Spain with a coverage of around 143,000 hectares. Spain is by far the largest EU adopter with 92% of the total (Clive, 2014). In contrast, regarding products

for food and feed uses, there are now 68 GMO already authorised and 58 pending on decision (Laaninen, 2015).

The consumer's right to know whether foods are genetically modified or contain GM ingredients in order to make an informed choice is the basis for the mandatory GMO labelling requirement. Labelling involves market segregation and a system to prevent commingling of GM and not GM food. However, this consumer's choice might not be completely real since there is a 0.9% threshold level allowed for adventitious presence of GM material in plant derived food products and also because GM-fed animal's derived products are exempt from labelling. Having this in mind it is interesting to consider that European livestock is heavily dependent on imported South America's soymeal where GM soy is widely cultivated. On the contrary there is hardly any GM food on the European market. This may be linked to the availability of non-GM alternatives as well as the labelling obligations. Retailers and manufacturers attempt to move away from the negative image GM food have in Europe. Labelling obligations requirements affects enormously imported foods, a fact that suggests that the consumer's right to know may have been used as an excuse for EU protectionism since at the international level, applicable international instruments do not recognize the consumer's right to know as a permissible exclusive basis for a GMO labelling system (Du, 2014).

To preserve consumer's choice, alongside with the labelling system a set of coexistence measures can be put in place throughout the process from cultivation to food processing to avoid unintended presence of GMO in other products, preventing potential economic losses. Here again discrepancies can be found. For some, the high degree of complexity, uncertainty, and direct costs associated with coexistence rules (minimum distance requirements for cultivation, liability and insurance measures) disincentives EU farmers to adopt GM crops (Qaim, 2009).

This restrictive and subject to extensive political interference legal framework, has constrained the development of GMO in the EU. As an example, the number of notifications for GMO field trials received in the EU since the now supersede, Directive 90⁄220⁄EEC on deliberate release into the environment of genetically modified organisms came into force, was over sixfold fewer than the number of applications received in the United States over the same period (Gómez-Galera et al., 2012). Outside of Europe, new GMO are being created, approved and cultivated at a pace exceeding that of EU approvals.

Methodology

A systematic review is a review of the literature according to an explicit, rigorous and transparent methodology (Frewer et al., 2013), with the purpose of gathering and analysing as many relevant research studies as possible on a specific question. In addition, this approach allows to limit and make visible potential researchers' bias.

There are a number of recent systematic reviews in the domain of food security studies, e.g. Candel (2014) on food security governance, Ringsberg (2014) on food traceability, Warren et al. (2015) on the association between urban agriculture and food security; and even some papers on GM specific issues: Frewer et al. (2013) on public perceptions of agri-food applications of GM or García Yi et al. (2014) and Klümper and Qaim (2014) on the impacts of GM crops. For our systematic review, the following steps were carried out.

Data collection protocol

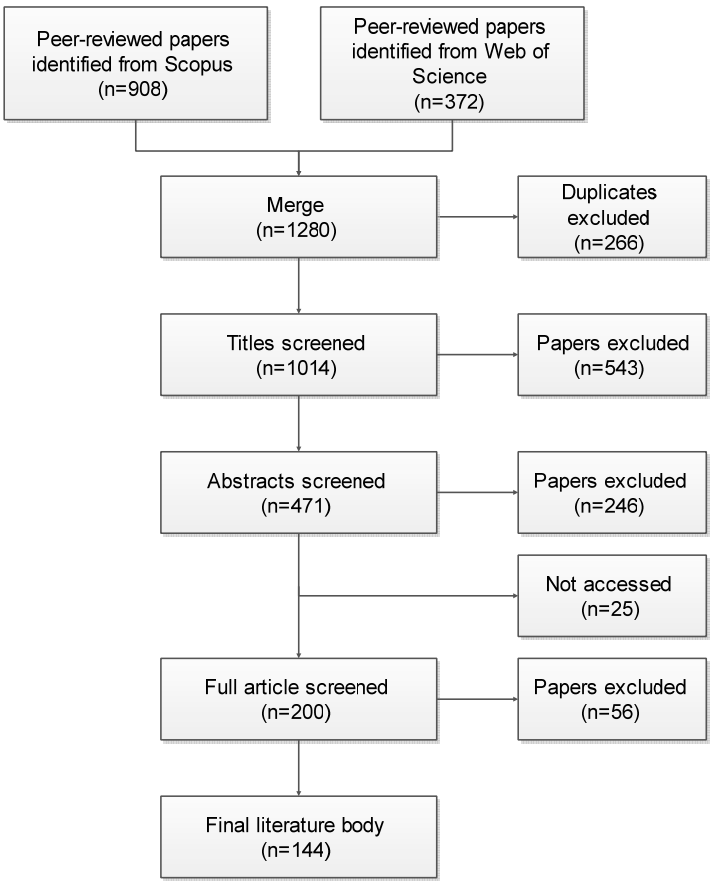
There is a broad literature, both academic and non-academic available on GM food. Candidate papers to be studied were identified through keyword searches in Web of Sciences (WOS thereafter) and Scopus. Both cover a significant majority of international peer-reviewed journals and are the two most extensive, popular and commonly used digital bibliographical databases.

The data collection process is shown in the flow diagram of Figure 1. First, the search terms were set up, tested and refined through several rounds of full search in WOS and Scopus (Table 1). The query was restricted to the titles, abstracts and keywords of the articles being searched and was used to search for academic articles or review produced since 2008. This initial year was selected since we considered the 2007-08 world food price crisis gave a renewed momentum to FNS concerns in the academic realm. These results were merged in a unique database in order to eliminate duplicates. References were managed with Mendeley. After that, titles were screened to remove those articles that, despite containing the search terms, were outside the scope of this review (e.g. biosensors, chemical detection, DNA sequences, PCR methods for the detection of DNA, etc.), or the abbreviation GM referred to extraneous issues (e.g. GMP Good Manufacturing Practices), or where the term European referred to a specific pest. Also articles focused on GM animals were not considered. From this first selected literature body 225articles were appointed as relevant for in-depth reading. Additional 25 articles where then removed from that list as they could not be retrieved (either not available from our university's subscription system or in a language other than English, French or Spanish). Full available articles were exported to NVivo, a qualitative data analysis software, and were read and evaluated again against the inclusion/exclusion criteria leading to a final literature body of 144 articles that were the foundation on which the conceptual maps are based. In this final stage, particular attention was paid to consider only papers addressing relevant topics within the EU food system, i.e. papers with a global focus or referred to other regions (North America, Asia, Africa..) were removed.

Table 1. Data collection search criteria

Web of Science	Scopus
Search data: 22/07/2015 **Final search string**: Search term 1 (AND) (biotech* or GMO or transgenic*) Search term 2 (AND) (europ* or eu) Search term 3 (AND) (agri* or food) **Date range**: since 2008 **Settings**: Web of Science core collection Science Citation Index Expanded (SCI-expanded) Social Sciences Citation Index (SSCI) Arts & Humanities Citation Index (A&HCI) **Results:** 372	**Search data**: 22/07/2015 **Final search string**: Search term 1 (AND) (biotech* or GM* or transgenic*) Search term 2 (AND) (europ* or eu) Search term 3 (AND) (agri* or food) Search term 4 (AND NOT) (GMBH)[3] **Date range**: since 2008 **Settings**: Document type: article or review Subject areas: all (4). Life Sciences; Health Sciences; Physical Sciences; Social Sciences & Humanities **Results:** 908

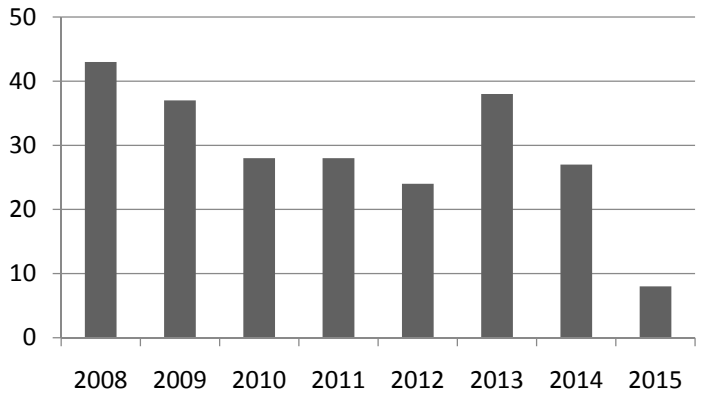
Figure 1. Data collection protocol



[3]GMBH is the German abbreviated for "company with limited liability". Papers were excluded after taking into consideration the relevant hits with the search string terms 1 +2 +3 +GMBH.

Next figure show the yearly distribution of considered papers.

Figure 2. Annual distribution of articles



There are some limitations on this review. First, the review is limited to academic peer-reviewed articles. Book chapters and grey literature (reports, conference papers, working papers and other documents from public bodies and think-tanks) were not considered. Second, there is a language bias in analysed papers, which resulted in the removal of a set of articles. In addition, a number of papers could not be retrieved due to accessibility constraints.

Constructing the concept map

The final outcome of this analysis is the presentation of the main findings of the studies on a concept map. This map tries to depict the relationships among a set of concepts. In this case, the nodes are variables that show food system processes, stakeholders' actions, … and the linkers express the cause-effect relationship among them and the sense (either + or -) of such relationship. All the linkers are associated to the reviewed studies found in the above search.

This layout allows to visually disentangle the mechanisms that, according to the literature, operate within the European GM-specific food system, and facilitates the identification of bounded cause-effects relationships and loops. Moreover, as all the linkers are associated to literature, this will allow to identify hotspots, i.e. nodes and linkers (or groups of nodes) where the concentration of articles reveals subjects of particular relevance and attention. As Stave and Kopainsky (2015: 321) argue, visual representations "*can serve to different purposes for different stakeholders: developing research questions, identifying policy leverage points, or building collaborations among people in different parts of the system*".

Although it is not within the scope of this paper, this concept map could be the basis for further and more sophisticated analytical developments, like Fuzzy Cognitive Maps (Kok, 2009) or System Dynamics (Stave and Kopainsky, 2015).

Results and discussion

In this section we present the outcomes of the analysis. For the sake of clarity we have drawn two concept maps: one revolving around GM agricultural production and GM and non-GM farmers, and a second on the consumption-related issues. In both cases, we have added the respective relevant policy nodes. Needless to say that features of the two maps overlap to a certain extent, providing insight to a global picture. In this regard, the nodes that appear in

both maps are highlighted. For each connection, the concept maps point out the sense of the relationship (+/-) and an identification number that refers, within the tables above, the papers that would be supporting such relationship.

Figure 1. Production-centred concept map

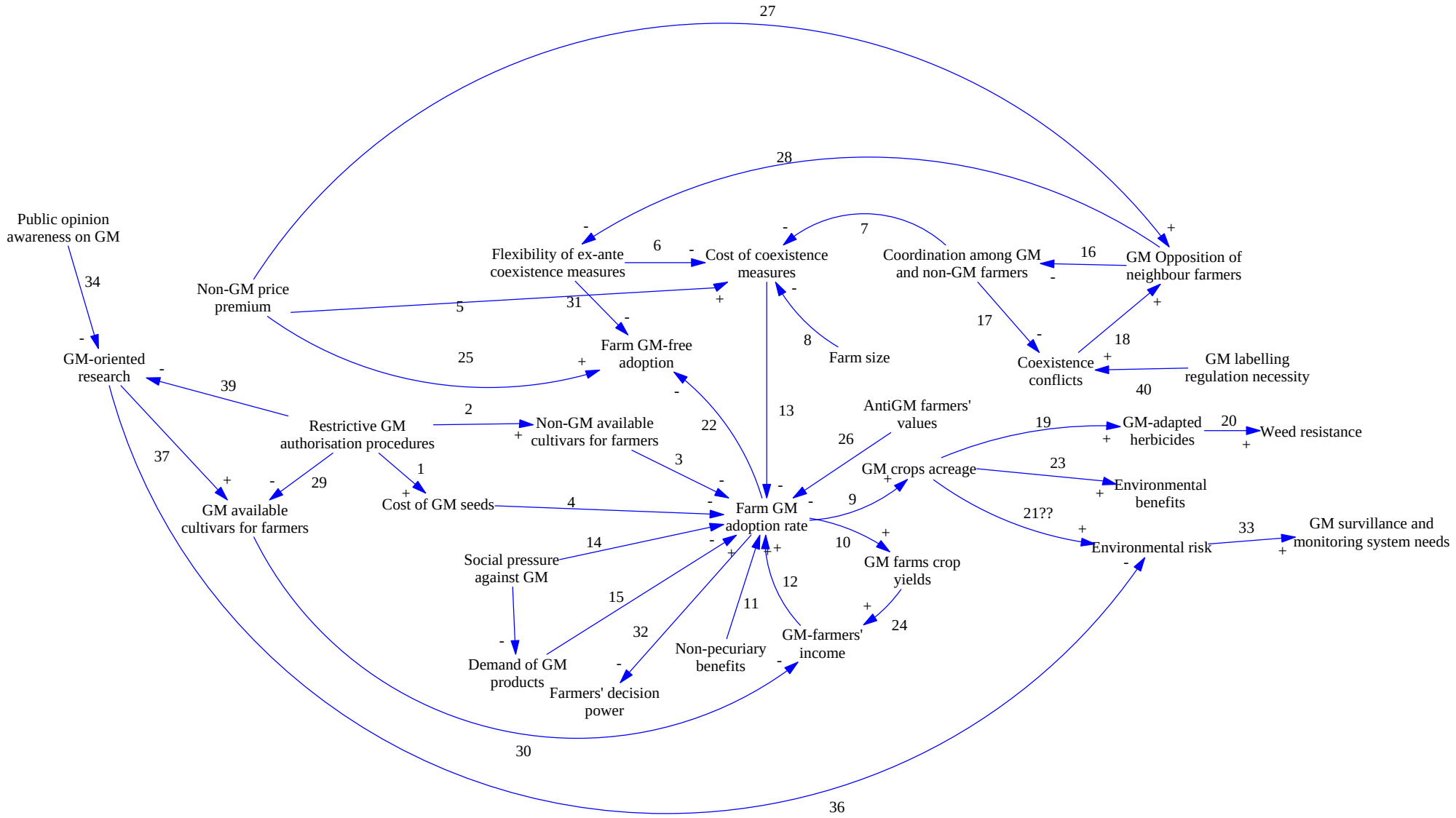


Table 1. Production-centred references

1.	Kalaitzandonakes and Magnier (2013); Park et al. (2011)
2.	Hilbeck et al. (2013); Kok et al. (2014)
3.	Hilbeck et al. (2013)
4.	Areal et al. (2011); Breustedt et al. (2008); Breustedt et al. (2009); Park et al. (2011)
5.	Ceddia et al. (2011); Quedas and Carvalho (2012)
6.	Bertheau et al. (2012); Chiarabolli (2011) ; Demont and Devos (2008); Demont, Cerovska et al. (2008); Demont et al. (2009); Demont et al. (2010); Demont, Daes et al. (2008); Devos et al. (2009); Devos et al. (2013); Le Bail et al. (2010); Pearsall (2013)
7.	Consmüller et al. (2009); Demont et al. (2009); Demont et al. (2010); Demont, Daes et al. (2008) ; Devos, Dillen et al. (2013); Gryson et al. (2009); Sanvido et al. (2008); Sanvido et al. (2008); Sausse et al. (2013); Skevas et al. (2010); Winter and Stoppe-Ramadan (2011)
8.	Breustedt et al. (2008); Breustedt et al. (2009); Consmüller et al. (2009); Gyau et al. (2009); Mosser et al. (2013); Sanvido et al. (2008) ; Sanvido et al. (2008); Van De Wiel et al. (2009)
9.	Park et al. (2011)
10.	Brooks (2008); Meissle et al. (2011); O'Brien and Mullins (2009); Park et al. (2011); Riesgo et al. (2012)
11.	Areal et al. (2011); Areal et al. (2012)
12.	Areal et al. (2011); Areal et al. (2012); Breustedt et al. (2008); Breustedt et al. (2009); Lassen and Sandøe (2009)
13.	Areal et al. (2012); Bertheau et al. (2012); Consmüller et al. (2009); Demont and Devos (2008) ; Demont, Cerovska et al. (2008a); Demont et al. (2010); Pearsall (2013)
14.	Areal et al. (2012); Hall (2008); Stephan (2012); Wesseler (2014)
15.	Areal et al. (2012); Hall (2008)
16.	Breustedt et al. (2008); Breustedt et al. (2009); De Cock Buning et al. (2011); Seifert (2008)
17.	Tricault et al. (2011)
18.	Tricault et al. (2011)
19.	Devos, Cougnon et al. (2008)
20.	Catarino et al. (2015); Devos, Cougnon et al. (2008); Graef (2009); Mannion and Morse (2012); Meissle et al. (2011)
21.	Graef (2009); Holst et al. (2013); Sanvido et al. (2012)
22.	Binimelis (2008); Cocklin et al. (2008) ; Lavigne et al. (2008); Mosser et al. (2013) ; Skevas et al. (2010)
23.	Brooks (2008); Mannion and Morse (2012); O'Brien and Mullins (2009)
24.	Brooks (2008) ; Riesgo et al. (2012)
25.	Riesgo et al. (2012)
26.	Lassen and Sandøe (2009); Seifert (2008); Stephan (2012)
27.	Levidow and Boschert (2008)
28.	Binimelis (2008); Levidow and Boschert (2008)
29.	Cantley (2012); Dillen et al. (2013); O'Brien and Mullins (2009); Szabala et al. (2014)
30.	Demont, Cerovska et al. (2008); Dillen et al. (2010); Dillen et al. (2013) ; Meissle et al. (2011)
31.	Ricroch et al. (2009)
32.	Morris and Holloway (2009)
33.	Meyer (2011); Smit et al. (2012); Wilhelm et al. (2009)
34.	Greener (2008)
35.	Sparrow (2010)
36.	Cichocka et al. (2011); Kvakkestad (2009)
37.	Kvakkestad (2009)
38.	Amman (2014); Tait (2009)
39.	Cantley (2012)
40.	Levidov and Boschert (2011)

Figure 2. Consumption-centred concept map

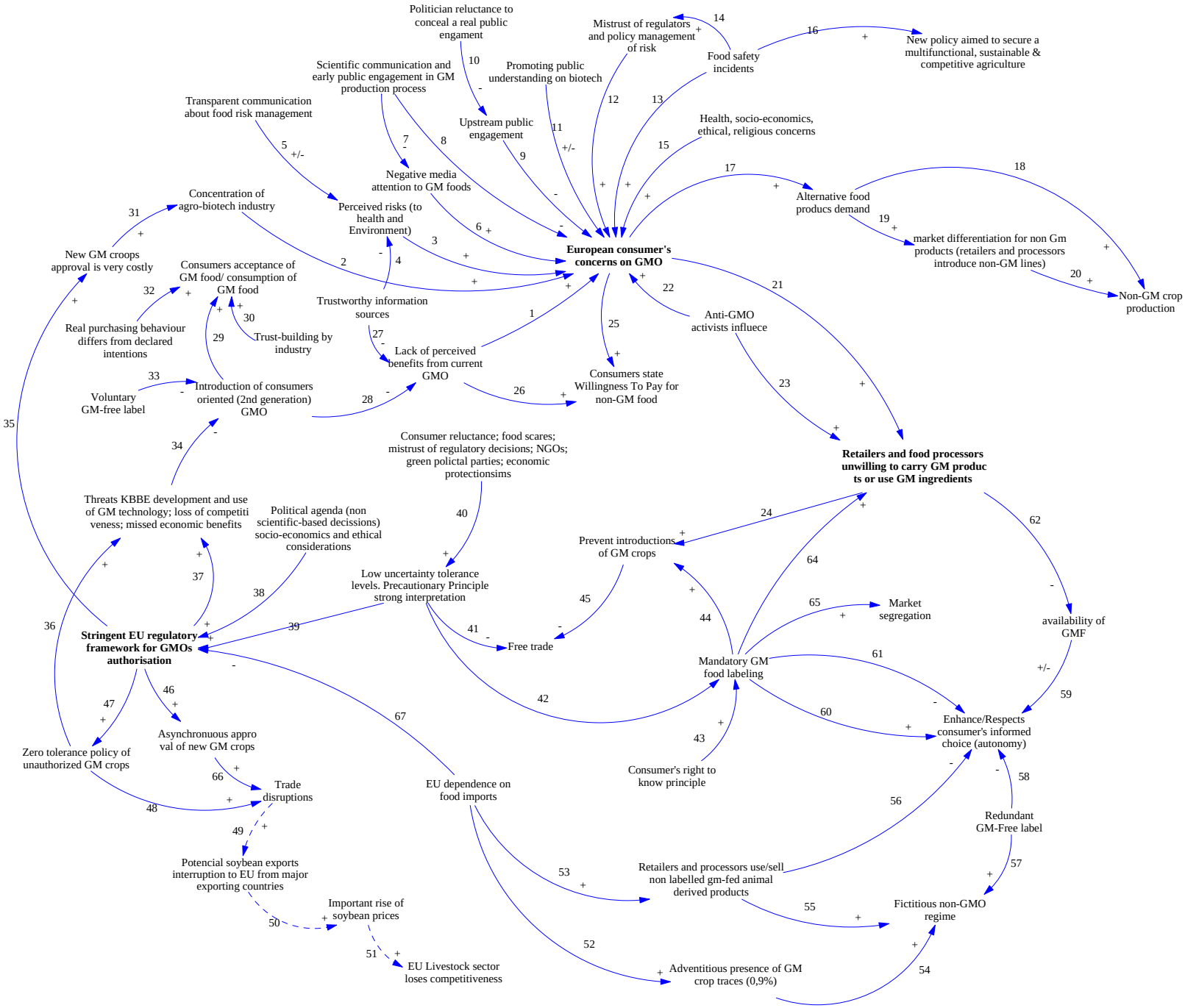


Table 1. Consumption-centred references

1.	Batista and Oliveira (2009); Batrinou et al. (2008); Boy (2014); Bremer et al. (2015); Canavari and Nayga (2011); Costa Font (2011); Knight (2008); Knight (2009); Lassoued and Giannakas (2010); Qaim (2009); Rodríguez-Entrena et al. (2013); Schenk et al. (2008)
2.	Martin (2013); Tait and Barker (2011)
3.	Bonaccorsi et al. (2010); Boy (2014); Bremer et al. (2015); Costa-Font (2011); Costa-Font and Gil (2009); Eggert and Greaker (2011); Knezevic et al. (2013); Kwieciński (2009); Martinez-Poveda et al (2009); Rodríguez-Entrena et al. (2013); Siipi and Uusitalo (2007); Tsourgiannis et al. (2011); Zilberman et al. (2013)
4.	Costa-Font and Gil (2009); Costa-Font et al. (2008); Martinez-Poveda et al (2009)
5.	Van Dijk et al. (2008)
6.	Flipse and Osseweijer (2012); Frewer et al. (2013); Qaim (2009); Zilberman et al. (2013)
7.	Flipse and Osseweijer (2012)
8.	Flipse and Osseweijer (2012)
9.	Kuntz and Ricroch (2012)
10.	Nielsen et al. (2011)
11.	Costa-Font et al. (2008); Kuntz and Ricroch (2012); Vanderschuren et al. (2010)
12.	Batrinou et al. (2008); Bertheau and Davison (2008); Burachik (2013); Frewer et al. (2013); Kwieciński (2009); Legge and Durant (2010); Lieberman and Gray (2008); Vergragt and Brown (2008)
13.	Batrinou et al. (2008); Bertheau and Davison (2008); Frewer et al. (2013); Knight (2009); Lieberman and Gray (2008); Ramjoué (2008); Zilberman et al. (2013)
14.	Kuiper and Davies (2010); Lassoued and Giannakas (2010); Legge and Durant (2010); Ramjoué (2008); Van Calster (2008)
15.	Bonaccorsi et al. (2010); Bremer et al. (2015); Devos et al. (2008); Eggert and Greaker (2011); Knezevic et al. (2013); Knight (2009); Siipe and Uusitalo (2008); Qaim (2009); Rodríguez-Entrena et al. (2013); Siipi and Uusitalo (2007);Tsourgiannis et al. (2011)
16.	Levidow and Boschert (2008)
17.	Konefal and Busch (2010); Nicholas et al. (2014); Tsourgiannis et al. (2011)
18.	Nicholas et al. (2014)
19.	Konefal and Busch (2010)
20.	Nicholas et al. (2014)
21.	Desaint and Varbanova (2013); Flipse and Osseweijer (2012); Rodríguez-Entrena et al. (2013)
22.	Konefal and Busch (2010)
23.	Konefal and Busch (2010); Zilberman et al. (2013)
24.	Batrinou et al. (2008); Canavariand Nayga (2011)
25.	Costa-Font et al. (2008); Eggert and Greaker (2011); Paarlberg (2010); Schläpfer (2008); Zilberman et al. (2013)
26.	Hartl and Herrmann (2009)
27.	Costa-Font and Gil (2009)
28.	Batista and Oliveira (2009); Canavari and Nayga (2011); Lassoued and Giannakas (2010); O'Brien et al. (2012); Qaim (2009); Rodríguez-Entrena et al. (2013); Schenk et al. (2008)
29.	Desaint and Varbanova (2013); Knight (2008); Novoselova et al. (2013); O'Brien et al. (2012); Rodríguez-Entrena et al. (2013); Rollin et al. (2011); Sleenhoff and Osseweijer (2013)
30.	Yee et al. (2008)
31.	Martin (2013); Qaim (2009); Tait and Barker (2011)
32.	Moses (2012); Sleenhoff and Osseweijer (2013)
33.	Rodríguez-Entrena et al. (2013)
34.	Gómez-Galera et al. (2012); Graff et al. (2009); Qaim (2009)
35.	Martin (2013); Qaim (2009); Tait and Barker (2011)
36.	Hobbs et al. (2014)
37.	Dillen et al. (2009); Fagerström et al. (2012); Gómez-Galera et al. (2012); Graff et al. (2009); Martin (2013); Masip et al (2013); Moses (2012); Qaim (2009); Raybould and Poppy (2012)
38.	Morris and Spillane (2008); Moses (2012); Smith et al. (2013); Vázquez-Salat and Houdebine

	(2013)
39.	Strauss (2008); Wohlers (2010); Wohlers (2015)
40.	Raybould and Poppy (2012)
41.	Strauss (2008); Lieberman and Gray (2008)
43.	Du (2014)
43.	Du (2014); Qaim (2009)
44.	Batrinou et al. (2008); Du (2014)
45.	Batrinou et al. (2008); Gruère et al. (2008)
46.	Burachik (2013); Davison (2010); Henseler et al. (2013)
47.	Davison (2010); Henseler et al. (2013)
48.	Davison (2010); Henseler et al. (2013); Kalaitzandonakes (2014); Roïz (2014)
49.	Henseler et al. (2013)
50.	Henseler et al. (2013); Kalaitzandonakes (2014); Philippidis (2010)
51.	Davison (2010); Henseler et al. (2013); Kalaitzandonakes (2014); Philippidis (2010)
52.	Bertheau (2011)
53.	Bertheau (2011)
54.	Inghelbrecht et al. (2015)
55.	Inghelbrecht et al. (2014); Inghelbrecht et al. (2015)
56.	Gryson et al. (2009)
57.	Inghelbrecht et al. (2015)
58.	Dannenberg et al. (2011)
59.	Siipi and Uusitalo (2010)
60.	Bertheau (2011); Du (2014); Gruère et al. (2008)
61.	Inghelbrecht et al. (2015); Siipi and Uusitalo (2007)
62.	Rodríguez-Entrena et al. (2013)
64.	Gruère et al. (2008); Inghelbrecht et al. (2015)
65.	Qaim (2009)
66.	Burachik (2013); Davison (2010); Henseler et al. (2013); Kalaitzandonakes (2014); Philippidis (2010)
67.	Masip et al (2013)

As explained in the methodological section, the mapping of the systematic literature review allows for the identification of hotspots, i.e. nodes (or clusters of nodes) of the conceptual map where the concentration of articles reveals subjects of particular relevance and attention. We focus on some of them, namely: the cost of coexistence measures as a key factor in explaining GM adoption, the implications of consumers' rejection to GM food and the Precautionary Principle approach adopted by the EU regulators on the GMO risk management.

Coexistence between GM and non-GM crops is one of these key hotspots. The EU allowed Member states to regulate national or regional coexistence measures based on a set of recommendations published on 2003[4]. Since then, States have developed and implemented their own regulations.

Much of the scientific debate (in most cases addressed by mix teams of economists-plant production researchers) has been on how to tackle the *newcomer principle* in the case of GM farmers and the degree of rigidity–flexibility of *ex-ante* coexistence measures. In particular, the literature insists on exploring the use of economic incentives in the frame of GM and non-GM agreements in order to find cost-effective coexistence solutions.

[4] Commission Recommendation, 23 July 2003 C(2003).

The European Commission published a second report in 2009[5] on the way member states had implemented coexistence measures. Interestingly, it concluded that there was not compelling evidence that legislative differences were a determining factor of farmers' GM adoption, which would had been demonstrated by the heterogeneous spatial distribution of GMO cultivation within countries with identical coexistence regimes. Other aspects, like the way GM technology fits farmers' agricultural values or the internal dynamics of the agrarian neighbourhood communities deserve further attention, so that more studies adopting a sociological approach are maybe required to better understand coexistence.

From the consumption perspective, the main hotspots are found at the nodes relating to consumers' perceptions about GM food. Indeed, regional, national and local surveys state that consumer's attitudes to GM food remain largely negative in European countries twenty years after their commercial release. Nevertheless, some works highlight that results are different for the application of biotechnology on pharmaceuticals. Perceived risks both to health and to the environment are the two most cited factors explaining this aversion to GM food. According to the literature, the still quite recent food and health incidents that hit Europe (the mad cow disease, dioxin contamination, the foot to mouth disease or more recently the E. coli outbreak) has led to a low uncertainty tolerance and high risk aversion among European consumers and a distrust on the ability of regulating authorities and the policy management of risk. Although the scientific data shows no record of negative effects on human health of GM food products (other than its possible allergenicity which also exits on conventional food) and they are considered "substantially equivalent" to non GM foods, consumers scepticism remains and explains the willingness to pay a premium price for non-GM food products.

However, several articles revel that there are a wide range of issues other than safety or risk that a consumer/citizen consider when deciding about GM. Socio-economic, cultural identities, personal values and attributes, ethical, dietary preferences or even religious beliefs need to be considered.

Furthermore, there is a general consensus pointing out that it is the lack of perceived benefits the main factor behind consumer's reluctance to GM food. Tangible benefits such as price advantage, taste and health benefits would change attitudes. Several studies concluded that the introduction of novel second generation GM food which include consumer-oriented improvements of product quality may consequently change their purchase intentions. Besides, the stated willingness to pay that consumers report in surveys to avoid GM food seems to bear little relation to the actual willingness to pay when the theoretical becomes practical.

According to some authors, in order to ameliorate the public perception of new technologies like transgenics, it is necessary to teach and inform the public of its advances. Schools should serve as a channel through which younger generations gain information. Nevertheless as it is also pointed, increased knowledge does not translate into greater acceptance, although it is necessary to make reasonable, informed decisions. Other voices point at an early upstream public engagement. A participatory horizontal approach to avoid the feeling of an imposed not demanded product.

[5]European Commission, COM(2009) 153 final.

Finally, another hotspot found regards policy regulations for GMO authorization. When compared to other national and international regulations procedures, the EU's is a stringent one. There is a general agreement in the literature that factors other than a science-based evaluation drive regulatory system governance. The literature points to a political agenda governing decision making, which is influenced by cultural context and socio-economic issues, where public opinion and interest groups have also influenced political decision-making. Indeed, within an environment of low uncertainty tolerance levels and prevalent cautious risk perceptions, the EU has followed a precautionary principle approach regarding biotechnology and driving regulatory policies. This view would have, generally speaking, emphasized the risk associated with GM products while minimizing benefits. Addressing these difficulties has become a major challenge for policy-makers, who have to find the midpoint between promoting innovation, aiming to develop a competitive knowledge-based bioeconomy and addressing ethical and cultural values. For some authors nevertheless this middle ground is not been met and Europe risks losing the competitive edge and social benefits.

This policy affects international as well as domestic economics. The EU is one of the world's largest traders in agricultural products and *asynchronous approval* of new GM crops, together with a zero threshold tolerance policy for unauthorized products, causes trade disruptions with food exporter's nations. Authors have contemplated several trade disruptions case scenarios rising concerns that, in the worst case scenario, would compromise the EU livestock industry due to its dependence on imports. This is why, according to those authors, the EU policy on GM food imports is less restrictive than the regulations covering GM agriculture.

Concluding remarks

The analysis has allowed to disentangle the complex mechanisms operating within and explaining the dynamics of the EU GM-food system. In addition, the combination of the mapping and the systematic literature review made possible to identify relevant hotspots concentrating the attention of the scientific community, as well as topics that have been much less addressed.

One of the aims of this paper was also to better connect the literature on GMO in Europe with the FNS implication. The review and the mapping of connections among issues reveal important implications of GM developments in the European Union in terms of FNS outcomes. Indeed, the production potential of GM crops that has been reported in a number of studies (higher yields, lower losses due to pests and diseases) has a clear impact in terms of food availability. Moreover, FNS takes into account food preferences and socio-cultural acceptability[6], so that availability should not be considered only in terms of total amount of food, but also in terms of the diversity (the balance between GM and non-GM food supply) and the embedded information (i.e. labelling) in order to make informed choices. In the same vein, prices of GM and non-GM food can be affected by changes in public regulations and stakeholders decisions, which would have food economic access implications. Stability, as dimension of FNS, is also at stake. For instance, issues like long term weed resistance, farms' long run economic viability or the adaptive capacity of cultivars open several questions

[6] Some authors argue that acceptability can be considered part of the utilization (adequacy) dimension, as cultural acceptability can become a part of the adequacy criteria (Brunori et al. 2015).

regarding the stability of availability. Finally, some authors add agency, as an additional FNS dimension, which refers to people, communities' or stakeholders' capacity to control the other dimensions (Brunori et al., 2015). The review has brought to the light a number of 'nodes' where actors' agency is at play, although this issues has received much less attention in the scientific literature.

However, despite these implications, the connections between the mechanisms operating within the GM-specific food system and the European food security outcomes have hardly been explicitly addressed in the literature. Few reviewed papers make explicitly this connection (see for instance O'Brien and Mullins, 2009).

Another of the purposes of the concept maps was to identify the main drivers of change, i.e. the nodes that trigger bounded reactions. In this regard, the main drivers identified in the literature relate to public opinion changes and its impacts on (i) public policies regulating labelling requirements, the rigidity/flexibility of coexistences measures and the procedures of new GM events authorisations; (ii) the competitiveness of European economy through opportunity loss and on the global market generating trade disruptions and (iii) the signals it sends to food system actors (producers, processors and retailers) by means of market demand and direct social pressure.

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