GM and non-GM supply chain co-existence and traceability: context and perspectives

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32 GM and Non-GM Supply Chain Co-Existence and Traceability: Context and Perspectives

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32.1 INTRODUCTION

It would seem impossible to discuss the co-existence and traceability of GMO and non-GMO supply chains in Europe without reviewing (i) certain issues which have led to their rejection by most citizens, whether or not they are socially or politically active, and (ii) the changes in agricultural production over the last few decades.

The failure of scientists and companies to understand this rejection of GMOS can be explained to an extent by the social questioning of the advantages of GMOs and, more generally, of various technological innovations and the uncertainty surrounding them, not to mention continuing related conflicts such as patentability.

32.2 BACKGROUND

32.2.1 Expertise

Market authorisations of GMOs are based on prior assessments of their health and environmental risk, conducted by national or international scientific panels, with varying levels of standardisation and attempts to reach a consensus (Bergmans, 2006; *Codex Alimentarius*, 2003; EFSA GMO Panel, 2008, 2010, 2011b; Kleter and Kok, 2010). The same panels of experts decide on co-existence regulations and ensure that the notifier's recommendations correspond to mandatory guidelines in terms of surveillance plans, while external experts may be called in to contribute.

While it enjoys the experience of previous expertise (drugs, chemical molecules), the assessment of health and environmental risks related to GMOs has progressed from a mainly molecular-based approach to a more systemic approach, admittedly with increasingly complex requirements, but which are not merely the sum total of lower levels (Anderson, 1972). Experts have learned how to assess GMO risks 'as they go', by gradually incorporating new data and requests. This, however, is far from providing the answers to all the questions that arise (Bonneuil and Joly, 2007).

32.2.1.1 Hard science versus soft science

The social, economic and ethical aspects of market authorisations are not taken into account in scientific assessments, whereas they are the reasons behind most of the opposition encountered.

Until recently, only Norway included social criteria such as sustainable development or advantages for developing countries in its assessments. This attempt to achieve a systemic approach is not without its (many) problems (Direktoratet for naturforvaltning, 2009; Kvakkestad and Vatn, 2008). Applications do not include such considerations, which are not provided due to the lack, for example, of EC obligations in cases where the request comes from a single country. This continuous work has to be distinguished from occasional reports of advisory committees

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on GMOs on socio-economic issues, such as the reports of the Dutch COGEM or British ACRE (COGEM, 2009).

The latest European recommendation on co-existence (2010) enables Member States to include social and economic criteria in their definition of their co-existence measures. It is regrettable that the European Commission did not take this further by requiring that applicants provide social and economic data with regard to the relevance of GMOs in their applications.

France has only recently created an Economic, Ethical and Social Committee (CEES) in addition to the Scientific Committee (CS) at the Haut Conseil des Biotechnologies (HCB, High Council for Biotechnologies) (Bertheau and Davison, 2011). This CEES discusses social and economic issues and includes politicians, stakeholders and three 'qualified experts' to draw up its recommendations. For some points a consensus is reached, for others a majority agreement; however the Committee is often criticised for conclusions such as 'some think this . . . while others think that . . .'. Such criticism is both uncalled-for, given that the system is still new and finding its feet, and above all hypocritical, as such a committee cannot be rightly asked to reach a consensus that society has not successfully reached after more than a decade of debate.

The experiences of this CEES are being observed on a European scale with various countries attempting to identify information that may enable them to encourage public acceptance of GMOs. Similarly, the introduction of economists and a sociologist within the HCB's Scientific Committee (CS) should provide new momentum to its expertise, if only in reference to Bourdieu's views of scientific authority (Bourdieu, 1976, 1997).

Following a short experiment in Britain (http://webarchive.nationalarchives.gov.uk/20100419143351/http://www.aebc.gov.uk/), only two countries have begun to take into account society's requirements, which roughly comprise a demand for participatory science and the democratisation of expertise (Ferretti and Pavone, 2009; Lengwiler, 2008). This follows a continuous approach, and is therefore less dependent on the case-by-case basis conducted by scientific bodies in some other countries, but the relevance of such an approach is still fiercely challenged by both scientists and some stakeholders of the HCB.

This demand for the democratisation of expertise is part of a broader, more fundamental social movement affecting a number of fields such as (i) electromagnetic radiation from mobile telephones or ultra-high voltage power lines, (ii) nanotechnologies and (iii) synthetic biology, to name but the most recent. In addition to citizens' conferences, based on an American process of 'consensus conferences' used in the 1970s, this broader expertise is set to provide answers on the general relevance of GMOs for society, a recurring issue in the controversy (Boy et al., 2000).

32.2.1.2 Independence and conflicts of interest

In addition to the European health crises mentioned previously (Bertheau and Davison, Introduction to this book), European citizens are calling into question the quality and independence of scientific expertise. They are concerned as much about certain biases in the expertise and conflicts of interest as lobbies in action and the 'revolving door' system of officials working in bodies of expertise.

This questioning of expertise is also due to the fact that scientific expertise is a social construct, despite this being refuted by 'hard science' scientists (Motion and Doolin, 2007). This social construct is a result of the frame of the expertise, value judgements on the bodies and the values upheld by each scientist on cross-disciplinary subjects. Various authors have stressed how experts very often make decisions on subjects that are at the boundaries of their knowledge, and therefore in an uncertain environment (Edwards, 1999; Joly, 2001; Latour and Woolgar, 1979; Levidow et al., 2005; Levidow and Marris, 2001; Mazur, 1985).

As highlighted by these authors, it would be unrealistic to think that scientific bodies can foresee the future without sufficient distance, background and previous data. The belief that experts have in their ability to project themselves into uncertain situations can only be an obstacle to their stances and stifle acceptance from their audience. These debates on GMOs are related to others on various health products or safety such as in nuclear power plants. The facts can only increase the public's apprehension and distrust in this expertise which, until now, consisted in more or less assuring that risks have been almost totally mastered.

Furthermore, these bodies' scientific expertise puts forward the concept of the established 'sound science', which has been undermined by various frauds and lobbies created by manufacturers to protect their interests, when the scientists themselves are not involved in conflicts of interest (Baba et al., 2005; Crawford-Brown, 2005; Diels et al., 2011; Gaskell and Allum, 2001; Hirsch, 2009; Ong and Glantz, 2001; Reynolds, 2004; van den Belt, 2003; Wertz et al., 2011). This 'sound science', a favourite among politicians such as the former US President G.W Bush and notifying companies, no longer enjoys the public's trust, while the public continues to have high hopes for scientific progress.

These various criticisms are also supported by attempts to reach a 'consensus' on scientific expertise, which runs

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the risk of poor assessments in situations of uncertainty (Levidow and Carr, 2007). This consensus desired by scientific bodies results, in particular, in the scientists themselves being doubted, as they are seen by the public as champions of an ideology, for example 'productivism' or 'scientism', and as a social body that defends its own interests. Most people therefore consider this 'consensus' to have been created at the expense of complexity and transparency. Moreover, the public can easily sense that this construction involves a certain contempt for citizens, who are deemed unable to sufficiently understand the great science and are condemned to live with uncertainty (Frewer et al., 2003; Gisler and Kurath, 2011; House et al., 2003; Joly et al., 2000; Kolstø, 2001; Levidow, 2003; Levidow and Carr, 2007; Marris et al., 2005; Marris et al., 2001).

In doing so, they echo sociologists, anthropologists and philosophers, including Habermas, in considering the idea that an expert procedure cannot be separated from moral considerations and values and be solely based on specialist knowledge (Habermas, 1971; Harding, 1992; Merton, 1973; Turner, 2001).

As stressed by Pierre Muller: 'the more complex a decision to take, the more political it is'; science is therefore often called upon to 'solve' social problems (Muller, 1995).

Expertise, just as science or technological innovation, therefore is not neutral, pure or impartial (Bourdieu, 1976, 1997).

32.2.1.3 *Expertise and counter-expertise*

This phenomenon of rejection of a certain type of expertise has only intensified with increasingly easy access to diverse and contradictory sources of information (discussion forums, blogs, social networks, etc., all powerful, fast and uncontrollable), fuelled by civil society's growing capacity for counter-expertise. This set of facts and beliefs (the latter not to be assimilated to conventional unfounded rumours) has led a large number of citizens to reject scientific 'truth' upheld by experts.

This scientific 'truth' is also undermined by its possible transmission through the actions – 'publicity' according to some stakeholders – of industrial lobbies who do not sufficiently consider the fears and demands of society (Delborne, 2008; Levidow and Marris, 2001; Miller and Harkins, 2010; Miller and Conko, 2004; Prat, 2011).

With information flow to consumer citizens constantly increasing, the recipients of this information are now filtering it more. This break, due to the growing importance of the recipient, means that communication is now more like a negotiation than knowledge transmission or sharing. Citizens have become active players in their information consumption and are considering the information received and exchanged with wider perspectives, particularly if it comes with an argument of authority. They therefore favour exchanges within their communities, in which they place their trust. Communication failure has consequently become the outcome of scientific expertise communication, while certain citizens' demands for participatory expertise generally aim at what they consider a necessary adaptation of the proposed innovations.

The comitology of expertise is a long process, into which the new facts with an impact on risk assessment can only be incorporated slowly and belatedly (see for example: Vaucheret and Chupeau, 2012; Zhang et al., 2012). The necessary time frame for the standardised incorporation of new questions into expertise procedure can only surprise citizens. These new questions may cast doubts on past expertise and come up against the impossibility of asking applicants to provide additional studies for the applications already submitted.

These delays in scientific expertise result in concern and distrust from lay citizens, further fuelled by 'scaremongers' that experts often admonish as being the cause of 'unfounded fears'.

32.2.1.4 *Scientists and lay people*

With the non-consideration of this reality in which citizens have lost some of their respect for scientific experts who are seen as subservient to 'scientism' and defending their personal values with regard to progress and productivism, the current controversy on GMOs can only reach a deadlock. This is what the Eurobarometers and other opinion polls reveal as regards both GMOs and science itself (Bucchi and Trench, 2008; Gaskell et al., 2005; Gaskell et al., 2010; Richard, 2011). When it comes to technological innovations, citizens now place their trust more readily in associations than in other information sources.

We are stuck in a situation in which scientists are from Mars and citizens are from Venus, to paraphrase Christoforou (2003). The non-inclusion of social factors in the GMO controversy is a major stumbling block.

It is fitting to consider the questioning of recommended co-existence measures in light of these general doubts surrounding scientific and technical expertise. These points are often considered by decision-makers and explain public authorities' choice of co-existence measures, but various authors deem them to be inconsistent with the European principle of 'proportionality'.

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In this many-sided debate, farmers, who remained relatively quiet and in the background for the first decades of the twentieth century, are now voicing their differences and questions about these agricultural innovations that may conflict with other land uses demanded by society (cf. Introduction of this book).

32.2.2 Agricultural productions and supply chains

Agricultural supply chains have undergone significant change over the twentieth century, basically evolving from subsistence-based farming in countries with a high-density agricultural population, at least for Europe, to industrialised production, an active sector of the market economy with a falling number of farmers and more futures markets, currently with increasingly speculative trends (Montfort, 2008). While this change is clearly visible in Western areas such as the USA, Europe, Russia and former Soviet countries, and some Asian countries such as Japan and China and others in Latin America, it has also affected many developing nations in Africa and less developed parts of Asia.

Over the last century, agricultural supply chains have been subjected to various technical changes, that have been more or less well accepted, with, for instance, the introduction of mechanical ploughing, a rise in the use of inputs and certified seeds – with increasingly hybrid varieties that must be purchased each year (Federico, 2008; Hurt, 2002; Mazoyer and Roudart, 2006).

This increase in agricultural production has also come together with more specialised productions; when niche markets are not the chosen path the signs of Taylorism and Fordism are often felt with resentment (Bonanno and Constance, 2001; Bonneuil and Thomas, 2009; Wolf, 2008). The necessary investments have led farmers to contract significant debt, resulting in financial instability (Agreste, 2010, 2011; Estenson, 1987; Pietola et al., 2011; Shepard and Collins, 1982).

The development of international trade in agricultural products has brought about a race for farmers to be competitive in order to withstand the increased competition. This need for competitiveness has generally been supported by export subsidy policies such as those in the USA and Europe. International trade has, for example, resulted in Senegalese rice being replaced by American broken rice in the national dish. This specialisation has also resulted in a reduction in the number of species grown, the erosion of the genetic diversity of cultivated varieties and an increase in the number of orphan species, through crop improvement and environmentally-friendly farming practices (Frankel and Hawkes, 2011; Moose and Mumm, 2008; Tadele, 2009).

A large-scale rural exodus also saw a drop in the number of farms in 'disadvantaged' areas such as mountain regions and the extension of farms in other regions with more 'competitive' farming methods. The average surface area of farms has constantly increased in Western Europe. In France for example, it was 10–20 ha in the nineteenth century, 20–40 ha in 1950 and is currently at 30–100 ha. The 200 000 farms over 40 ha accounted for almost 75% of French farmland in 2001 and the trend has continued since. This phenomenon was first observed in Western European Member States is now visible in Eastern Member States.

This extension of total cultivated area per farm has naturally led farmers to cut the time it takes to farm one unit of land, particularly when the farmer or spouse must also have a second paid activity, which is very common (Briggeman, 2011; Delame and Thomas, 2007). GMOs were clearly a welcome means of reducing workloads.

At the same time, the development of international trade in agricultural products also resulted in a reduction in the number of operators (Green and Hervé, 2006). These are players in the agricultural commodity mass markets and in niche markets such as the European non-GMO market. Production specialisation, often conducted at the expense of farmers in developing countries, has made the Americas the leading net exporters of agricultural commodities, in particular for mass-produced animal feed. Similar specialisation attempts for exports have been made in countries with large fertile plains such as the Ukraine, where arable land has been sold or leased to agricultural conglomerates.

While being encouraged to produce more, farmers also face other demands such as the removal of the most toxic molecules and the reduction of inputs (European REACH Directive, *Ecophyto 2018* in France, etc.). These demands, often summed up under the term 'intensively ecological' agriculture, are the subject of debate among farmers and more generally in society.

The restructuring of farms has turned the rural environment of a stable and reassuring social framework into a precarious and constantly changing environment. This is the case even in Eastern Member States such as Romania, where large cooperative farms have survived. Lastly, as the total cultivated area per country drops due to increasing urbanisation, real estate pressure, and therefore tension and competition, are on the rise for these areas as for yields.

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It is against this backdrop of tense competitiveness and specialisation that farmers must select their production methods. Farmers torn between contradictory demands and conflicting production options are common in this context. This situation influences their position and view of GMOs. This is why those who are against GMOs speak of risks to the great displeasure of those who are in favour of them.

32.2.3 'Feeding the world'

Feeding the world has always been the challenge for agriculture, while it has not prevented climate- or economy-related famines, as noted by C. Walford as early as the nineteenth century, in his description of more than 350 famines (Brun and Dupin, 1975).

Farmers are the suppliers of foodstuffs that are now distributed on a global scale. Demographic growth has brought about serious food crises, such as the hunger riots of 2007–2008, or those projected by various models including those of the Club of Rome in the 1970s (Bell, 2009; Colombo, 2001; Evenson and Gollin, 2003).

These gloomy forecasts, which did not prove correct, perhaps because the models were erroneous or because solutions were found such as the green revolution of the 1970s, are once again topical with the global population expected to reach nine billion by 2050 (although some demographers have called this estimation into question) (Dahan-Dalmedico, 2007; Dahan-Dalmedico and Armatte, 2004; Lutz et al., 2001; Sauvy, 1949; UNFPA (United Nations Population Fund), 2011; United nations Conference on Trade and Development, 2011a, b; Vieille Blanchard, 2010).

The forecast with regard to available arable land to feed this increasing population varies between regression to a slight improvement, but in poorer soil and climate conditions.

Two arguments have then re-emerged in political and agricultural circles on the 'feeding the world' issue and farmers find themselves between the two. One involves attempting to double farm production by continuing to improve yields and cultivated hectarage, while the second favours the reorientation of production types and of the global development and consumption model (Drogué et al., 2006; Foley et al., 2011; Godfray et al., 2010; Juma, 2011; Paillard and Treyer, 2010; Paillard et al., 2011).

In the first case, GMOs would enable a clear rise in production through increased yields and crops suited to unfavourable cultivation conditions (drought, high salinity in soils, etc.). This scenario is underpinned by a vision concerned with improving the well-being of populations based on economic growth in line with current trends and in which GMOs naturally have their place.

In the second case, generally championed by agricultural development specialists and agronomists in particular, authors identify various factors other than agricultural production as causes of past, present and future famines. They highlight in particular that the majority of people suffering from famine are actually farmers. They also note the low level of support that local agriculture received due to the development of an international trade in foodstuffs from developed nations and countries with export subsidies.

These authors also denounce the fact that farmers in developed countries are urged to turn to other, non-food productions, with a view to developing supply chain trade and finance. Here is a common example: almost 40% of US maize is used for the production of bio-fuels on fertile land while these bio-fuels are of little agro-environmental interest and have a generally negative energy balance (inputs for production versus energy recovered after harvest) (Bringezu et al., 2012; FAO, 2008; Landeweerd et al., 2009; Searchinger et al., 2008). This observation seems to have been taken into account in the USA, where bio-ethanol subsidies have recently ceased. This decision is probably not unrelated to the improvement of US energy independence following increased production of unconventional oil and shale gas.

International trade in agricultural commodities, in addition to the strong development of futures markets and speculation, is one of the factors causing the high price volatility, and even some of the famines, in recent years. These authors stress the close relationship between areas of famine and situations of conflict or corruption which reportedly prevent the excess production of some areas being transported in time to starving, often displaced, populations. In light of this increased global agricultural specialisation, they recommend returning to local production and alternative methods with an increase in income for local populations.

In these scenarios, GMOs are either not considered or rejected, as they do not meet the needs of low-income populations and would even increase their dependence on inputs, marketed seeds, and in turn companies.

Both scenarios present almost identical considerations as those put forward by the 'green revolution', whose balance sheet has received mixed reactions from the authors (Alessandrini, 2010; Bishaw and Turner, 2008;

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Evenson and Gollin, 2003; Huang et al., 2002; Paul. et al., 2003; Ruttan, 2004; Swaminathan, 2010).

It seems as though GMO supporters have not learned from the controversial recent past, in terms of their positions or the communications means implemented. Since the same causes produce the same effects, it is inevitable that these positions are surrounded by tension in terms of the major issue of world hunger despite the overproduction of the last decades.

Faced with industrialised agriculture (for example through animal production dependent on soybean and maize produced on very large areas), other farmers, often criticised as 'opting for' decline and having a backward-looking vision of agriculture, have no choice but to conduct publicity stunts such as destroying GMO crops, and such acts are related to a history of resistance and radicalism. The difference in available resources, financial in particular, between these two visions of agriculture, and more generally of society, is one of the causes of those positions that are deemed extreme. Civil disobedience follows on in a new construction of legitimacy, including scientific, arguing for a state of emergency and necessity (Doherty and Hayes, 2012; Hayes, 2007; Seifert, 2006; Seifert, 2009).

Among the other factors that play a part in farmers' choice of GM or non-GM crops is the need to maintain multiple production methods. A particular type of technological pluralism that means, as illustrated for the energy mix, that the availability of electric light does not prevent some from continuing to light candles if they so wish (Hermitte, Chapter 23 this book).

Farmers must make their own decisions based on their cost–benefit analysis, which in reality is almost impossible. The methodology and structure of this type of analysis approach are still under discussion, particularly for quantitative approaches (Morris, 2011). Farmers therefore make contradictory demands: the conventional request for preserved freedom but within a framework providing protection. They often base themselves on regulations and laws, even if it means using various levers to arrive at the most favourable result for themselves.

Rather than aiming to feed the world, economic opportunities override in the choice of production methods and land use. Because of this, the subsidies, while increasingly decoupled, of the European CAP or US exports model the agricultural landscape (Alstom, 2007; Bock et al., 2002; Mayrand et al., 2003; Russo, 2009; Young and Westcott, 2000). The need to secure income also explains the success of gene stacking, similar to blanket phytosanitary treatments being used instead of simply using treatments when necessary.

It should also be pointed out that some of the differences in European farmers' behaviour in comparison to most of their American counterparts could also be related to differences in the availability of land not used for agriculture. The USA has very large natural parks, whereas agriculture is everywhere in the landscapes of the EU and some Asian countries. Hence the use of concepts in the EU such as 'high nature value' or the desire of some farmers to openly display their attachment to their land and local traditions, which are uncommon in the USA as farmers take more distance from their land, considering it merely as a means of production. These considerations have also been noted by society and may go some way to explaining the positions of some farmers.

These differences in the acceptance of agricultural innovations such as GMOs have resulted in separate production supply chains that must provide traceability to satisfy consumers. This implies the ability to produce and segregate products from the different production methods and to ensure fair practices in the food trade and consumer information.

32.3 CO-EXISTENCE

Going beyond storage in silos, co-existence of supply chains is generally considered to be sufficiently controlled by companies. The actual costs of co-existence remain unknown, a fact that is not specific to GMO and non-GMO supply chains. In theory, the question of who should bear the resulting additional costs will be valid for a long time to come and in practice will be answered by non-GMO supply chains.

The notion of co-existence between GMO and non-GMO crops is a mainly European one, in that it is organised by public standards. Co-existence, between GM and for example organic farming, and damages paid for economic losses are recent topics of debate in the USA, despite the lack of labelling for GMO products and the common use of private identity preservation (IP) to meet the requirements of exports toward the EU and some Asian countries. This interference is due to the demands of organic farmers, following the authorisation of GM alfalfa, the first perennial to be authorised, but the expected development of molecular farming may also be put forward (Beecher, 2011; Coexistence Working Group et al., December 2003; GMO Compass, 2011; Grossman, 2008; Perkowski, 2011; Smyth and Kershen, 2006; Spök, 2007).

Yet before addressing the issue of co-existence from a purely agricultural standpoint, that is as part of an option to maintain technological pluralism and consumers' freedom of choice, it is necessary to review the issue of the *in situ* preservation of genetic diversity. The latter, which is mainly dynamic, is still required to improve varieties and cannot be dependent on banks of frozen genes.

32.3.1 GMOs and genetic resources

While the EU is a diversification centre for some crops, such as sugar beet for which gene exchanges with *Beta maritima* must be minimised, the question of preserving genetic resources is topical in other parts of the world, such as maize in Mexico.

This example has been selected due to both the large surface areas of GMO maize cultivation in the world and the controversy that has arisen around the preservation of genetic resources in this diversification centre (Foyer, 2010). In addition to the controversy over the possible presence of GMO maize in Mexican farmers' native 'criollo' (landraces) varieties and the risk of contamination of resources preserved at the CIMMYT (International Maize and Wheat Improvement Center: CGIAR), the question of compensation payable to Mexican farmers who have worked for centuries to obtain maize and the varieties currently cultivated is also important.

In more general terms, this question addresses open-pollinated crop seeds (also called 'peasants' seeds') obtained through participatory selection (Bocci and Chable, 2008; Osman and Chable, 2009).

The issue of preserving 'peasants' seeds' has been raised relatively little in current works on co-existence. The same applies to redress, financial or other, for GMO presence in these local varieties which have biological features that differ considerably from the hybrid varieties used in co-existence studies.

If it were agreed that diversification centres and crop seeds obtained through participatory selection should be preserved, two points would have to be addressed: (i) which technical measures must be taken to ensure this preservation and who would be in charge, and (ii) which type of compensation would be applied (for this exclusion from an agricultural technological innovation)? Should states provide compensation for local farmers? If so, in what form and to what extent? Should some international bodies compensate these states? This question is related to the more general issue of international demands for the preservation of forest carbon stores, such as the Amazon rainforest, or natural reserves that are sources of biodiversity such as in Honduras, with regard to oil production. The question of ecosystem services has not yet been addressed as co-existence's concern.

If these needs and demands from local populations are not taken into consideration, the battle lines of the GMO controversy will become further entrenched.

32.3.2 Co-existence conditions

As already highlighted by many authors and noted in the introduction of this book, co-existence conditions in the field are easier for mainly autogamous crops such as soybean. It is, however, important to remember that autogamy rates never reach 100% and that some pollinating insects can adapt to new agricultural landscapes. Except for considerations in the monitoring of seed sales, the effectiveness of which has not been proven (the current unauthorised GM rice crops are an example), this always partial autogamy may explain at least part of China's reluctance, as a soybean diversification centre, to grow GM soybean, while retaining its potential to export non-GM soybean at a higher price (Bertheau and Davison, 2011).

The difficulty comes with mainly allogamous crops such as maize and in particular rapeseed (Cawood, 2011) and its feral plants, or perennials such as alfalfa (AgBioWorld, 2011; Bagavathiannan et al., 2011). Many studies have considered how to set up such co-existence, a generally complicated task with costs that are unclear for GMO and non-GMO producers, but always recommend flexible co-existence with the exception of the network of 'GM-free regions' and of a few publications on GMO-free dedicated production areas.

Although they are often favoured by biotechnologists, (cf. the Transcontainer project by de Maagd and Boutilier, Chapter 5 this book), bioconfinement (also called biocontainment) methods such as cleistogamy of rapeseed, or chloroplast transformation techniques, are far from being commercially available. Only a very few bioconfinement techniques are near commercialisation, most are at the research/laboratory stage (Fargue et al., 2006). Moreover, seeds producers/companies generally use bioconfinement methods to produce hybrid seeds or as a tool in plant breeding (thus also making hybrids). It is thus very difficult to believe that seed companies would be accepting of providing these bioconfinement tools to farmers – even under drastic contractual conditions – to facilitate co-existence in the fields. They will probably keep these 'tools' for their own purposes as currently.

Bioconfinement methods have received a bad press since the 'Terminator' affair and it is therefore likely that the social cost of their introduction will prevent their routine use, with the exception of specific cases such as molecular farming (Bustos, 2008; ETC Group, 2007; Masood, 1998).

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Co-existence conditions are therefore difficult to achieve, particularly in the application of the European recommendation that all measures remain 'proportionate to the objectives'. Their definition generally requires modelling to identify the minimum conditions and above all the local conditions, genotype and climate and soil micro-conditions, and so on which must be considered to ensure flexibility (cf. for example Della Porta et al. 2008). In a general sense, the requirements for co-existence have led to research on gene flow, atmospheric pollen dispersions and knowledge of critical points for production. Yet the reluctance surrounding this expertise still stands.

For all species, these studies include and must consider in their models many parameters such as crop height, the cultivar that emits the pollen, the size of the transmitting and receiving fields, the partial protection of borders around GMO or non-GMO fields, fragmented landscapes, instant and average wind speed, annual pollen emission variations and so on. However, many of the factors required for these studies are not standardised, such as sampling plans, or used, such as real-time quantitative PCR, deployed downstream of the supply chains (Bellocchi et al., this book; Chamecki et al., 2011; Chamecki and Meneveau, 2011; Della Porta et al., 2008; Dupont et al., 2006; Fargue et al., 2005; Helbig et al., 2004; Honnay et al., 2005; Jarosz et al., 2004; Marceau et al., 2011; McLauchlan et al., 2011; Palaudelmàs et al., forthcoming). This series of factors influences gene flow and leads to a never-ending race to refine the models that require a more systemic approach, but which clearly do not fit with the current political tempo (European Committee of the regions, 2007).

No systemic approach has yet resulted from co-existence studies, which have therefore continued to use an expensive and time-consuming case-by-case approach, in which each cultivated taxon requires new efforts and sparks new questions due to its particular features. For example, the persistence of feral plants for rapeseed or the probable rise of volunteers of maize due to climate change (Devos et al., 2011; Schafer et al., 2010; van de Wiel et al., 2011).

32.3.2.1 The case of maize

If we consider maize as an example, it being the most studied crop, it can be noted that despite more than a decade of work, it has not yet been ascertained at what distance the adventitious presence of GMOs would be zero (Della Porta et al. 2008; Luna et al., 2001). While US guidelines require 1.6 km for total isolation, new results demonstrate the presence of fertile pollen at more than 2 km (Brunet et al., Chapter 6 this book). These results corroborate the empirical observations of pollen clouds noted by seed producers. The isolation distances for seed production were set over a long period of time and may yet prove to be insufficient for 'GMO-free' thresholds of less than 0.9% (Luna et al., 2001; OECD, 2011). Such dispersal of viable matter over long distances has been commonly observed for pollen and fungal spores (Bannert and Stamp, 2007; Fenart et al., 2007; Glemnitz et al., 2011; Hallenberg and Kúffer, 2001; Knispel and McLachlan, 2010; Luna et al., 2001; Nagarajan and Singh, 1990; Pan et al., 2006; Van de Water et al., 2007; Westbrook and Isard, 1999).

Various models have been developed particularly for pollen dispersal (Allnutt et al., 2008; Angevin et al., 2008; Aylor, 2005; Aylor et al., 2006; Aylor et al., 2003; Bannert, 2006; Beckie and Hall, 2008; Dietiker et al., 2011a; Dietiker et al., 2011b; Flannery et al., 2005; Goggi et al., 2006; Gustafson, 2008; Gustafson et al., 2006; Jarosz et al., 2005; Jarosz et al., 2003; Jarosz et al., 2004; Kawashima et al., 2004; Klein et al., 2003; Lavigne et al., 2008; Lipsius et al., 2006; Loos et al., 2003; Ma et al., 2004; Marceau et al., 2008; Marceau et al., 2011; Viaud et al., 2008; Viner and Arritt, 2010; Weekes et al., 2007 ; Yamamura, 2004). Two major types of modelling can be identified, the consequences of which on practical co-existence measures vary significantly, particularly for 'GMO-free' thresholds of under 0.9%.

These models have not been compared using the same experimental data. This approach would have provided useful information for decision-makers, leading to amended models and a greater consideration of certain elements such as spatialisation (Faivre et al., 2009).

One model, however, stands out for its presence in European reports and its use in decision aids, such as abacuses or other decision support systems (Angevin et al., 2008; Bohanec et al., Chapter 25 this book; Bohanec et al., 2008; Messéan et al., 2006). It nevertheless has many limitations, not to mention the difficulties concerning its practical implementation.

This model for determining co-existence measures was used in a particularly original way in France where the opinion of the French HCB's Scientific Committee (CS) on technical co-existence measures recommends reverting back to the seed/tuber/root units to facilitate co-existence, particularly due to the effect of the HGE (Haploid Genome Equivalent) unit and gene stacking on co-existence capacities (Comité scientifique, Haut Conseil des biotechnologies, 2012). This change in units, at variance with the European recommendation to use the HGE unit, is a problem for fair practice in trading, access to the European

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single market and farmers' compensation. For the latter, the maximum thresholds of adventitious GMO presence would be calculated using seeds in the field, according to gene stacking in surrounding fields, while the HGE unit would be used for the marketing of production downstream of the supply chain. Contrary to what could be expected of a scientific body, this recommendation to change units comes on top of that to disregard measurement uncertainties and sampling errors.

This opinion has come under strong criticism in France, from both scientists and GMO opponents, due to its attempt to artificially reduce the effect of gene stacking on final GMO content. The reaction to this opinion can be summed up as 'breaking the thermometer to bring down the patient's temperature'.

Another grievance concerns the references for some crops which are very old and mostly taken from corporate studies. In addition, the abacuses from this model do not specify the quantiles, and therefore the confidence intervals, for the recommended co-existence measures.

Some scientists and stakeholders have also noted that the recommended approach simply states the shortcomings of prior co-existence studies, if we consider the HCB's Scientific Committee's final recommendation to monitor adventitious presence in the field over several years. This recommendation does not state how farmers can revert to the previous situation in the event of contamination that significantly exceeds projections, particularly in (farmers' own) 'peasants' seeds obtained through participatory selection.

The future of other maize co-existence models remains highly uncertain.

Without casting aspersions on the quality of each of the models, none of which have been evaluated (Wallach et al., 2006), it can be noted that, as for risk assessment, the HCB's Scientific Committee has combined scientific results and non-neutral constructions in order to arrive at a specific social result, such as the diminished effect of gene stacking. This opinion on co-existence is therefore a social construct that is a far cry from pure and neutral scientific expertise (Bourdieu, 1975, 1976, 1997; Dahan-Dalmedico, 2007; Dahan-Dalmedico and Armatte, 2004; Latour and Woolgar, 1979; Vos, 2008). The only possible refutation of the model used in the HCB's Scientific Committee's opinion will be the observation of the effects of recommended co-existence measures, a nationwide experiment that may be difficult to bear in social terms.

The opinion and recommendation of the HCB's Scientific Committee (CS) and Economic, Ethical and Social Committee (CEES) on co-existence in France agree on the recommendation of structures fostering dialogue among 'GMO-free' production players which may result in specific production areas (Comité économique éthique et social, Haut Conseil des biotechnologies, 2012; Comité scientifique, Haut Conseil des biotechnologies, 2012).

The draft order of the French government which has just been submitted to the European Commission for conformity checks only mentions the Community threshold (i.e. 0.9%). It provides for a minimum distance of 50 m of isolation distance between GM and non-GM fields or 9 m of non-GM corn/maize around GM field. The French government thus did not take into account the 'scientific' advice of the HCB, to use the measurement unit recommended by the EC – that is the HE unit (based on DNA), as the GMO content increases rapidly when GMOs are 'stacked' – but instead used a kernel counting measurement unit, which is not affected by the stacking level.

A European programme, launched in 2012, aims to offer various tools and measures, including a GIS (Geographic Information System) for the implementation of co-existence measures, for maize in particular.

32.3.2.2 Models and implementation of co-existence measures

The scientific community has failed to finalise most of these models and to provide practical tools for public authorities: optimised programmes to reduce calculation times or cloud computing among national or European systems, interfaces with the computers of meteorological services and land registries where possible to avoid wasting implementation time, user-friendly interfaces to facilitate their endorsement by the civil servants whose job it will be to roll out the measures on more local levels, considerations on how to organise the distribution of computers over the territory and interfacing with negotiation tools and so on.

We are far from the practical applications required by politicians in exchange for their finalised research funding.

There is a great risk that these models may have been 'oversold' to political decision-makers, even in the absence of their 'estimation' (validation) with regard to independent data. We must ask whether we are asking too much of these models and whether we expect unreasonable results from them.

There are several imperfections and shortcomings in the models (such as inability to predict the pollen dispersal over a fragmented landscape from results and modelling obtained with a few adjacent experimental fields) – models which, moreover, are generally not 'validated' with independent data not used in the modeling process – used to

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predict pollen flows and thus to establish co-existence measures. Scientists and companies are calling for 'proportionate' measures, as provided for in the European recommendation, though this wish in all likelihood remains unattainable.

Is there a better solution that respects the principle of proportionality other than that of farmers being able to make their own, individual, choices? This could probably be better achieved through improved territorial organisation. Such organisation, with appropriate negotiation structures, is also urgently requested in the HCB CEES' recommendation, in line with the conclusions of the Co-Extra research project (European Commission, 2010).

32.3.3 Co-existence and costs

Co-existence still raises various questions on various levels.

The first question involves deciding who will pay for co-existence costs along the supply chains. While the European recommendation provides that these costs will be borne by GMO producers for the production step, there is no mention of who should pay downstream.

The Economic, Ethical and Social Committee (CEES) of the HCB has therefore once again raised the issue of co-existence measures' payment along supply chains. A basic principle suggested in the 2003 version of the European recommendation, but not carried over into the 2010 version, was that new entrants, that is GMO producers, pay for the costs incurred by their entry to the market. However, in practice, the provision to date only covers compensation to non-GMO farmers for adventitious presence in their production under very restrictive conditions. In reality, conventional or organic farmers pay the additional costs incurred (analyses, certifications, storage, other segregation aspects along the supply chains). It is therefore unlikely that the supply chain segregation costs will be allocated to GMO producers who argue that non-GMO productions would enjoy the best prices, which effectively means that the additional costs of supply chains' co-existence are passed on to consumers.

A second question concerns the necessary research for determining the co-existence conditions of other crops. The consideration of costs and the duration of the research required to draw up the current models for a single crop, maize, suggests that co-existence in cases of other crop species will not enjoy such in-depth studies. It is likely that a model such as rapeseed will be selected, as it enables various new factors to be considered in the models, such as the effect of insect pollinators, the persistence and flowering of volunteers, dispersal around entry points – such as harbours – or along roads leading to storage silos. It seems unlikely, however, that other crops will be studied, such as alfalfa for its perennial character.

As a result, public authorities will once again be forced to take non-proportionate measures, if the political climate requires them to continue to take non-GMO producers into account. Yet will Europe consider the co-existence requirements of wheat, alfalfa or rapeseed, despite external pressure aimed at crop authorisations to maintain the 'competitiveness' of European agriculture?

As stated previously with regard to the preservation of genetic resources and 'peasants' seeds, co-existence between GMO and non-GMO crops cannot be considered simply in terms of its economic dimension of financial redress. Moreover, the European principle of proportionality supposes that the adventitious presence of GMOs in non-GMO crops is reversible. In addition to the lack of scientific data, this is the question surrounding the proportionate management of two crop types.

Having started co-existence studies on certain crops, and in light of international treaties such as the WTO, will Europe have a choice of crops for co-existence? Will it have the will and resources for this? Could the early international recognition of quality signs such as AOC (the French controlled designations of origin) and PGI (Protected Geographical Indication) act as leverage?

32.4 TRACEABILITY

32.4.1 Overview

Food traceability is completely expected by consumers, who will not suffer shortcomings for reasons of both food safety and the adulteration of expensive niche foodstuffs.

This traceability is now effective for authorised GMOs. European regulations now make the provision of GMO identification and quantification methods mandatory. This European measure facilitates international trade as these methods are provided free of charge to states that are not members of the European Economic Area (EEA). Some third countries that use mass as the unit of measurement of GMO content can also use conversion factors to meet their regulatory requirements.

The question of unauthorised GMOs has changed significantly in the EEA with, for example, the definition of a low level presence (LLP) of GMOs, unauthorised in the EU, for animal feed (EURL-GMFF, 2011; European Commission, 2011; Henshaw, 2011). In addition, more streamlined approaches used by laboratories to detect unauthorised or unknown GMOs have emerged thanks to the ENGL and similar national initiatives (Holst-Jensen et al., in press;

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Ruttink et al., 2010a; Ruttink et al., 2010b; Tengs et al., 2010). European concerns surrounding asynchronous and asymmetric authorisations are now shared with third countries, which bodes well for international harmonisation (GAO (US General Accouting Office), 2008).

The detection of unknown GMOs is based on two approaches: the matrix approach – supported by decision support systems – and differential quantitative PCR. It also enjoys the support of the JRC[1] (Joint Research Centre) in Ispra and the ENGL (European Network of GMO Laboratories), which now have long-standing experience in this field.

The JRC also takes part in capacity building in developing countries, which can subsequently control imported GMOs based on the databases of the Cartagena Protocol, and check that their exports comply with the regulations in the countries importing them.

This ability to detect GMOs can only improve health safety, unrelated to GMOs, in these countries through the use of concepts, standards and methodologies created for GMOs in other detection areas, such as those of allergens and toxin producing organisms.

32.4.2 Probable changes

Several changes can be expected in coming years.

It is probable that the new European regulation on LLPs in animal feed will reopen the discussion on the unit of measurement of GMO content to be used.

The new GMO production methods (meganucleases, oligonucleotides, etc.) will probably require the implementation of other methods, such as LCR or SNPlex, able to detect specific mutations, if the organisms resulting from the use of these new techniques come under Directive 2001/18 or Regulation 1829/2003 or forthcoming legislation (Chaouachi et al., 2008; Lusser et al., 2011).

As some notifiers are having their certified reference materials (CRM) made by the AOCS (American Oil Chemists' Society) rather than the JRC-IRMM (Institute for Reference Materials and Measurements, an institute of the JRC), it is likely that there will be a shortage of calibrants. These may be replaced with plasmids, alternative reference materials, for identifications and quantifications based on GMO inserts' border fragments. Yet these alternative CRM will not replace the ground seeds such as those currently prepared by the JRC-IRMM, in particular for screening methods routinely used for the matrix approach. Laboratories will therefore have to pay more to meet their needs.

The use of thresholds under 0.9%, such as the 0.1% threshold for French 'GM-free' crops, will also bring about the following: (i) either the production of appropriate calibrants, which can be obtained with plasmids. The currently available detection methods were validated using as a lower limit the 0.1% value. To be able to quantify below this 0.1% value, we need to get reference materials below that value but we also need to adapt the methods, which were not developed to work below 0.1%;. (ii) Or the use of sub-sampling methods (Berdal et al., 2008; Kobilinsky and Bertheau, 2005; La Mura et al., 2011). One alternative would be that operators continue to use the current contractual system of 'negative PCR' products (Comité scientifique, Haut Conseil des biotechnologies, 2012; European Commission, 2010; Hannachi, 2011). Such quantification requirements around 0.1% could also be necessary for GMOs in animal feed around the LLP threshold (European Commission, 2011).

Significant efforts must be made to standardise methodologies, decision trees and other decision support systems for the detection of unauthorised and unknown GMOs. Given the cost of international standardisation for the initial standardisation phase (1999–2006), it is highly likely that the standardisation process will go directly through laboratories and focal points such as the JRC-IHCP (Institute for Health and Consumer Protection, a JRC institute hosting the European Reference Laboratory for GMO Food and Feed [EURL-GMFF]).

32.5 CONCLUSION

Some authors consider GMO crops to be the third agricultural revolution. As with all agricultural innovations, GMOs are rejected by a portion of the population and of producers. This rejection is often misunderstood by scientists in charge of risk assessment or co-existence measures.

Cost–benefit analysis, and more generally social science issues, must be better incorporated into scientific expertise so that society's questioning of the direction taken by farmers, as well as by society as a whole, may be taken into greater consideration. Society as a whole is no longer satisfied with peremptory statements on the absence of known risks or that GMOs are one of the best solutions to 'feeding the world'.

Expertise must also include the impact of agricultural practices' changes, induced by GMO cultivation, which cannot be dissociated from society's choices. One of the many examples illustrating GMO crop issues is the contradictory results with regard to the effective trends of use of quantities of herbicide since the introduction of GMOs (Expertise collective CNRS-INRA, 2011).

Consequently, the development of resistant insects or weeds has become a normative issue to be incorporated in scientific assessments of the consequences of GMO crop adoption. Until now, such questions were upstaged in a 'chapter' of 'best farming practices' and companies' stewardships and therefore cleared of 'case-by-case' GMO assessments.

Are the current 'case-by-case' assessments still relevant? The probable introduction of crops for molecular farming will certainly further exacerbate these doubts, as will the recent developments in epigenetics and the observation of animal gene regulation by microRNA of ingested crops.

Society's increasing demands for transparency and participatory assessments cannot be brushed aside by scientists. As information circulates at an ever faster rate, this general demand for participatory expertise in relation to associations' increasing capacity to develop counter-expertise must be taken into account in the field of scientific expertise. The creation of two bodies, one scientific and the other made up of stakeholders, can only contribute to finding a solution if the two bodies work closely together. This is far from the case in the unique, French, experimentation we know.

These questions from society are clearly noted by farmers who consequently question production types (commodities or niche markets) according to economic opportunities and social trends.

Co-existence between GMO and non-GMO crops must be achieved through specific and general surveillance plans for human and environmental health, the guidelines of which have changed in recent years (EFSA GMO panel, 2006, 2011a; European Commission, 2009). Society will therefore have to bear new additional post-marketing costs, due to the use of private products with only a few benefit holders. As is the case with other health or phytosanitary products, the question arises of who will bear these additional costs (Cowan, 2011). A question rather similar to the one about the tragedy of the commons (Hardin, 1968).

Many studies have already began on a national level and also as part of a recently launched European research project (ACRE, 2004; Amanor-Boadu, 2004; Anonymous, 2009; Beckie et al., 2010; Carpenter, 2011; Collier and Mullins, 2010; Deng et al., 2008; Devos, 2008; Environment Agency Austria Umweltbundesamt, 2011; Graef, 2009; Hawes et al., 2010; Hepburn et al., 2008; Marvier et al., 2007; Pascher et al., 2011; Reuter et al., 2010; Sanvido et al., 2007; Sanvido et al., 2011; Schmeller and Henle, 2008; Schmidt et al., 2008; Smit et al., 2012; van den Brink et al., 2010; Wal et al., 2003; Wolt et al., 2010; Zughart et al., 2008). The relevance of such specific and general surveillance plans is clear with regard to observations in various third countries (Adler, 2011; Bagavathiannan et al., 2011; Davis et al., 2008; Krupke et al., 2009; Lu et al., 2010; Marquardt et al., 2008; Schafer et al., 2010).

General surveillance plans might be used as part of more general biovigilance plans, and therefore territory surveillance plans (Alcalde, 2006; Bartsch et al., 2006; Bartsch et al., 2007; Delos et al., 2007; Directions régionales de l'agriculture et de la forêt -Service régional de la protection des végétaux des régions Aquitaine et Midi-Pyrénées, 2007; Environment Agency Austria Umweltbundesamt, 2011; Hintermann et al., 2002; Kleppin et al., 2011; Ministerio de medio ambiente y medio rural y marino. Spain, 2011; Monkemeyer et al., 2006; Paré-Chamontin, 2010; Public Health Agency of Canada, 2002; Schmidtke and Schmidt, 2007; Wilhelm et al., 2009). It is however likely, given current cases and practices, that the costs of these surveillance plans will be for the most part borne by Member States and only to a small extent by notifiers (Bayer BioScience N.V., 2009; Monsanto Co., 2009a, b; Tinland et al., 2006).

At a time when Member States' resources are continuously diminishing, it can be expected that new public spending incurred without compensation from (consent holder) companies will be poorly received and could rapidly trigger new discord. While one of the reasons why citizens have rejected GMOs is the lack of any apparent direct benefits, it would be necessary to consider larger participation from notifying companies in this post-marketing surveillance, as is the case for the validation of GMO detection methods.

Co-existence and traceability in GMO and non-GMO supply chains, and more particularly in the field, cannot therefore be dissociated from a broader social movement that calls into question technological decisions, social choices and who bears costs (Levidow et al., 2005). What has to a greater extent been understood by politicians, who are more receptive to voters and therefore citizens, needs to be taken further into account by scientists.

Yet, does science have its place in public debate?

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