Should Turkey Adopt GM Crops?

A Social Multi-Criteria Evaluation for the Case of Cotton Farming in Turkey

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Abstract

This paper analyzes the decisions to approve and adopt genetically modified (GM) cotton farming in Turkey by using social multi-criteria evaluation. Four different methods—business as usual (BAU), ecological (ECO), GM, and good agricultural practices (GAP)—were assessed via environmental, social, and economic criteria. Results showed that GM was preferred when only economic concerns were considered, and ECO was the method of choice when only the social dimension was prioritized. When economic and social dimensions were jointly considered, GAP was the compromise solution. Findings of the study help understand motives, decision mechanisms, and policy outcomes in the GMO context.

JEL Codes: Q16, Q18

Introduction

Genetically modified (GM) crops were first commercialized in 1995, and several countries have allowed their cultivation since then, but a significant number of countries, especially in Europe, still oppose it. As of 2011, GM farming is undertaken in 29 countries covering an area of over 160 million hectares (James, 2011), but GM crops still continue to generate intense public debate and controversy. Some claim that genetically modified organisms (GMOs) avoid problems of intensive agriculture and lead to beneficial outcomes in economic and environmental terms, such as higher profits for farmers given lower input costs, more environmentally benign use of pesticides and herbicides, and even higher yields in some places (Qaim, 2005; Brookes and Barfoot, 2009; Ervin et al., 2010; Dannenberg et al., 2011). Others draw attention to the potential negative impacts of GM crops on human health and biodiversity, and argue that GMOs are driven not by need but by corporate profit (Altieri and Rosset, 1999; Shiva 2001, Schubert, 2002). Overall, the uncertainty surrounding GMOs continue to generate agricultural policy dilemmas in national and international arenas.

There are diverse perceptions and attitudes regarding biotechnology, and distributional conflicts among participants of the debate, including scientists, industrialists, environmentalists, and consumers, implying that controversies regarding GM crops and farming cannot be solved simply by appealing to economic or scientific principles (Binimelis 2008). In assessing whether to allow or ban the GM cultivation of a specific crop, it is expected that the quality and legitimacy of decision-making will be a central concern in the process—a logic well-established in the European Union (EU) legislation framework on GMOs based on the precautionary principle. As Kivilcim (2010) and Aerni (2010) note, according to the precautionary principle, political decisions on whether to take a potential risk should be based on societal priorities.

Moreover, decisions on approval should ideally take all possible alternatives and their socioeconomic and environmental implications into account, and examine them in a participatory and transparent forum.

The literature on GMOs is diverse. There is a large group of studies analyzing the ex-post economic impacts of the decision to adopt GM crops on farmers (e.g. Qaim and Traxler, 2005; Zilberman et al., 2007; Brookes and Barfoot, 2009, 2011; Ervin et al., 2010). Most of these studies are at the farm level, and rather than addressing the wider debate on the acceptability or necessity of GMOs, they often reduce the problem to the individual sphere as though farmers were in charge of deciding what they want to cultivate (Binimelis, 2008; Devos et al., 2008). Another group of studies explicitly focuses on the environmental impacts of GM crops (e.g. Wolfenbarger and Phifer, 2000; Dale et al., 2002; Snow et al., 2005; Brookes and Barfoot, 2011). There are also many other studies looking at one particular social aspect of the issue, such as regulation/law/governance (e.g. Levidow and Marris, 2001; Kvakkestad and Vatn, 2011); food safety (e.g. Wilkinson et al., 2003; König et al., 2004, Romeis et al., 2008); ethical concerns (e.g. Cooley and Goreham, 2004; Gregorowius et al., 2011); and scientist/consumer/public perceptions (e.g. Marris et al., 2001; Kvakkestad et al., 2007; Brossard, 2012). Yet, only a few studies investigate the triple performance—economic, social, and environmental—of GM farming relative to alternative agricultural practices. Factors that underlie decisions by policy-makers to approve GM crops, and the importance they assign to different dimensions of the issue are not investigated comprehensively either (Zilberman et al., 2007).

On this background, this paper frames the GM cotton approval discussion in Turkey in the context of a socio-political process where conflicts must be resolved between competing interests, and between people who hold different value systems and with different priorities. As of 2012, Turkey is at the stage of allowing the import of three types of GM corn to be used as animal feed, mainly poultry, and is considering approving several other crops for GM farming to better compete in world markets. Within this process, the case of cotton farming is particularly interesting. Cotton is a core competitive product for Turkey in the textile industry and although GM cotton is not consumed as food by humans or animals, and does not entail any direct health concerns, there is still an ongoing tension between the state, biotech companies, and civil society regarding the use of biotechnology for cotton production. This was particularly apparent during the protest campaigns of the "No-to-GMO Platform" in Turkey, formed by over 80 national and international NGOs. Therefore, it will be necessary to pay particular attention to governance issues while addressing this public policy problem, and manage the delicate balances of choices and priorities among social actors well (Kvakkestad and Vatn, 2011).

In this context, this paper assesses four different cotton farming alternatives—business as usual (BAU), ecological farming (ECO), GM farming (GM), and good agricultural practices (GAP)—using social multi-criteria evaluation, where multiple dimensions and objectives are considered simultaneously in evaluating and ranking these alternatives. The set of economic, social, and environmental criteria used in this evaluation were chosen based on an extensive review of the cotton production and GMO literatures, and in-depth interviews conducted with several key stakeholders and experts in Turkey. Illustrative examples of multi-criteria evaluation already exist in the literature as a conflict management tool, particularly in the evaluation of public projects and policy problems in relation to various issues, including water use, industrial development, energy investment, and agricultural practices (e.g. De Marchi et al., 2000; Stirling and Mayer, 2000; Qiu, 2005; Kallis et al., 2006; Salgado et al. 2006; Gamboa and Munda, 2007; Scolobig et al., 2008; Munda and Russi, 2008).

This paper employs multi-criteria evaluation in particular for framing the GM cotton debate in Turkey, to achieve the following: (i) investigate the underlying issues that divide social actors on GM farming, (ii) gain more detailed information about alternative agricultural practices and understand how and why the status quo is maintained, and (iii) reveal the priorities of policy-makers that are implicit in the GM approval or rejection decision. This exercise is, of course, more than just an economic analysis of the feasibility and consequences of the decision to approve GM cotton; it is also a politically relevant and flexible learning tool.

The GMO Debate

Worldwide, GMO politics are severely divided between the anti-GMO and the pro-GMO camps. The former accuses the latter "of pushing the introduction of GMOs into agriculture without adequately considering health and environmental risks," and the latter claims that the anti-GMO camp exaggerates the "potential risks out of proportion in order to manipulate public opinion against this new technology" (Marris, 2001, p. 545). The pro-GMO camp argues that the assertions of the anti-GMO camp "are not related to science and technology considerations but are of a political nature and influenced by ideological views of activist groups," especially those in Western Europe (James, 2011, p. 24). Table 1 summarizes issues raised for and against GM crops in terms of benefits and risks.

<<Table 1 About Here>>

In policy circles, the debate on GMO regulations is taking place mainly between the USA and the EU: The former, and its followers, are mild and open in their attitude to this new technology and the latter is more conservative. While, according to Anderson and Jackson (2006, p. 69), the conventional explanation for the EU-USA differences in GMO regulations is based on the perception that "Europeans care more about the natural environment than do Americans, and trust their food safety regulators less," the opposition in Europe is led not by consumers, but by lobby groups for agricultural chemical companies. In a similar vein, Graff and Zilberman (2004) note that European chemical companies, facing an increasing stringency in pesticide regulations, focused their R&D on more environmentally friendly chemicals and have mainly lagged behind in biotechnology developments.

In parallel with global developments, GM discussions were introduced to Turkey's agenda in the late 1990s. Although several field trials were conducted for different crops (e.g. cotton, corn, and potatoes) in this period, apart from some information regarding their location and duration, their main results were not officially disclosed, placing doubt on the transparency of the decision process. In 2000, Turkey signed the Cartagena Protocol on Bio-safety (SCBD, 2000), which was later ratified by the Turkish Parliament. The draft National Biosafety Law, based on this Protocol, came into force in late 2010 and included requirements and guidelines on the import, labeling, sales, control, and processing of GM products (Erkut, 2010; Artemel, 2010; 2011). Today, a group of scientists and big farmers in Turkey are explicitly for the adoption of GM crops, claiming that GMOs would increase agricultural production and solve a number of problems for the farmers (Dobos and Karaali, 2003). In contrast, many civil society organizations that came together under the No-to-GMO Platform, in line with the resistance movement in Europe, argue that the widespread use of GM crops would present risks to the environment and have severe socioeconomic consequences.

These differences in opinion illustrate the need for further discussion of the matter in Turkey as well, and in particular, for a collective decision-making process that involves moral, scientific, cultural, and political perspectives in addition to economic considerations, thereby giving a ”voice” to a range of non-reducible indicators and legitimate understandings and values. The call for a multidimensional approach that allows for the simultaneous consideration of different perspectives is one of the main reasons why social multi-criteria evaluation was put forward as a promising and appropriate framework for dealing with complex real world problems, which is presented in the next section.

The Social Multi-Criteria Evaluation Framework

Multi-criteria assessment methods have proven useful in the presence of complex decision-making problems where multiple dimensions, objectives and constraints have to be considered simultaneously. A typical multi-criteria problem (with a discrete number of alternatives) may be described in the following way: A is a finite set of n feasible actions (or alternatives), and m is the number of different points of view or evaluation criteria $g_i = 1, 2, \dots, m$ considered relevant in a decision problem, where action a is evaluated to be better than action b (both belonging to set A) according to the ith point of view if $g_i(a) \geq g_i(b)$ (Munda et al., 1994).

From an operational point of view, a major strength of multi-criteria methods is their ability to allow an integrated assessment of the problem at hand. Munda (2004a, 2008) offers an illustrative example of a multi-criteria problem as the experience of buying a new car, where a choice must be made based on the performance of a number of alternative cars, according to a given set of evaluation criteria (e.g. price, speed, safety, design, or color). Here, the evaluation criteria may be incommensurable (for instance, price of the car in dollars, speed in km/hour and safety as an index) and different vehicles may be favored under different criteria. The problem is that, generally, there is no available alternative that simultaneously optimizes all criteria, and thus compromises must be made to arrive at a decision.

The situation becomes even more complicated when there is more than one decision-maker involved in the decision-making process, as in the case of a couple or family, wherein the perceptions, values, and interests of those involved differ. Consequently, to choose evaluation criteria in a complex and collective decision-making process, it is necessary to first decide what is important for different social actors, and what is relevant for the representation of the real-world entity (Munda, 2004b). Recognizing the need for participation in public decision-making problems, Munda (2003) proposes the social multi-criteria evaluation method, which was explicitly designed to enhance participation and transparency, the main idea being that results of an evaluation exercise depend on how a given policy problem is represented; thus the assumptions made, and the interests and values considered have to be clarified.

Munda (2005) and Munda and Russi (2008) present the main steps that should be taken in the application of a social multi-criteria evaluation framework as follows: (i) identify relevant social actors, by means of institutional analysis; (ii) define social actors' values, desires, and preferences, mainly through in-depth interviews and focus groups; (iii) generate policy options and evaluation criteria; (iv) construct the multi-criteria impact matrix, which synthesizes the scores of all criteria for all alternatives (Janssen and Munda, 1999); and lastly, (v) apply a mathematical algorithm to obtain a final ranking of the available alternatives (numerous options are available, e.g. Arrow and Raynaud, 1986). The following section will frame the GM cotton farming debate using social multi-criteria evaluation.

Policy Alternatives and Evaluation Criteria for Cotton Production in Turkey

Turkey is both the world's sixth largest cotton producer and one of the largest importers of cotton, due to high demand from the textile and clothing industry comprising eight percent of Turkey's GDP and 16 percent of total domestic industry capacity. Turkey produced 803,000 tons of cotton on average annually in the 2005-to-2009 period (TUIK, 2011), and still imported 956,000 tons of cotton in 2009, mainly from the USA, Greece, Turkmenistan, and India (USDA, 2011). Overall, the production and industrial use of cotton is important for Turkey, and, hence, input use efficiency and sustainable production are crucial issues.

Cotton farms in Turkey are currently mostly small-scale (average farm size: 5.6 hectares) and family-run (Kooistra and Termorshuizen, 2006); hence, production is still labor intensive. Moreover, while the expansion of irrigated lands has led to increased pest infestation especially in Southeastern Turkey since 1996, the indiscriminate use of fertilizers and pesticides caused soil quality and fertility to deteriorate (Yilmaz and Ozkan, 2004; Özertan and Aerni, 2007; Kaygusuz, 2010). In this context, GM technology is seen as a critical turning point and put forth as a new cotton production alternative with large environmental and economic gains (Brookes and Barfoot, 2009). Conversely, GM opponents argue that other farming alternatives such as organic or integrated pest management (IPM) would also reduce pesticide use, and have similar positive environmental impacts without threatening biodiversity.

Against this background, this paper addresses the GM cotton debate in Turkey based on four main production alternatives: business as usual (BAU), ecological farming (ECO), GM farming (GM), and good agricultural practice (GAP). BAU is the current cotton production technique in Turkey; GAP is a reformed version of BAU and involves the more efficient use of resources and inputs within an integrated pest management (IPM) framework. It limits but does not ban the use of chemicals. When GMO seeds are used in an IPM setting, additional rules are introduced for the pre- and post-release monitoring of the cotton and product labeling, forming the GM alternative; refuge zone requirements may also be involved to prevent the development of pest resistance. Finally, in the ECO alternative, all farming activities are conducted using current organic farming standards of the EU (EU, 2007). Briefly, no synthetic chemicals or GM seeds are used in crop production, and the process is monitored by an independent certification institution.

Table 2 gives a detailed description of these alternatives inspired from the categorization by Gregory et al. (2002), and Stirling and Mayer (2000).

<<Table 2 About Here>>

To identify the suitable evaluation criteria by which to judge these alternative production methods, care was taken to cover all the important aspects of the problem at hand given the diversity of interests. To this aim, fieldwork consisting of two main phases was conducted in 2009. First, a desktop study of agriculture and agro-biotechnology in Turkey was carried out, where official documents, brochures and activity reports, websites of governmental and non-governmental organizations, and newspaper and journal articles were reviewed. Second, 23 semi-structured in-depth interviews were conducted with relevant state bureaucrats, cotton farmers, seed producers, representatives of non-governmental institutions, and other experts. The evaluation criteria gathered from the fieldwork, which was then used in setting-up the impact matrix, are presented in table 3

<<Table 3 About Here>>

Constructing the Multi-criteria Impact Matrix and Ranking the Alternatives

This section focuses on how each alternative performs with respect to the evaluation criteria listed above. Criterion scores were determined objectively, independent of stakeholder perceptions, mainly by relying on literature findings and empirical evidence, in the context of Turkey. These criterion scores were then used to rank alternatives based on a mathematical aggregation algorithm, details of which are provided in the Appendix.

The Environmental Dimension

Agro-Biodiversity: As mentioned by Srivastava et al. (1996), and Brookfield and Stocking (1999), agro-biodiversity is a multi-dimensional concept. Four sub-criteria that reflect this multiplicity were used as proxies to evaluate the performance of each alternative: i) *The Environmental Impact Quotient (EIQ) of Chemicals Used*, assessing pesticides and providing both quantity and toxicity adjusted information about their use; ii) *Area of Land Used for Unit Production,* evaluating agricultural land holdings of alternatives; iii) *Loss of Genetic Variation within Species,* checking whether farmers are specializing in a specific crop variety or not; and iv) *Loss of Indigenous Knowledge,* assessing the local knowledge, environmental adaptations, and human interactions levels for each alternative. Table 4 shows the performance scores of all the alternatives in these four sub-criteria:[1]

<<Table 4 About Here>>

The pair-wise comparison method and the ranking procedure discussed in the Appendix were applied to table 4, which revealed the final preference ordering showing the minimum negative impact on agro-biodiversity to be: ***ECO>GM>GAP>BAU***.[2]

Unintended Gene Flow Potential: The complexity of the ecosystem makes it impossible to measure the exact probability of gene flow. This is why in the literature it is more common to look at whether the probability of the unintended gene flow is greater than zero. In such a binary outcome context, the probability of gene flow appears to be greater than zero only in the GM alternative and, hence, the preference ordering is ***ECO~BAU~GAP>GM***.

Greenhouse Gas (GHG) Emission: According to Lal (2004), agricultural practices create three main sources of GHG emissions: Primary sources, which are emissions caused by farm machinery use; secondary sources, being the emissions caused by producing, transporting and packaging agricultural inputs (fertilizers, pesticides etc.); and tertiary sources, which are emissions caused by the construction and manufacture of farm buildings and equipment. Considering that all alternatives perform the same in terms of tertiary sources, the rank of the alternatives based on the primary and secondary sources is $GHG_{ECO}<GHG_{GM}<GHG_{GAP}<GHG_{BAU}$ and the preference ordering is ***ECO>GM>GAP>BAU.***

The Social Dimension

Level of Competition in the Input Market: Competition in input providing markets has two dimensions: The number of total input providers in the market referring to the monopolization level of the market, and the market share distribution of these providers referring to farmer dependency on specific providers. Considering these two dimensions, the following preference order emerges for level of competition: ***ECO>GAP>BAU>GM.***

Public Health Considerations: Two sub-criteria were considered in calculating the impact of each alternative on public health; the *health impact of the chemical input* and the *degree of uncertainty in relation to health impacts.* While alternatives were ranked as ECO<GM<GAP<BAU according to the first sub-criteria, uncertainty due to the presence of a transgene is only relevant for the GM alternative, giving the rank ECO=GAP=BAU<GM in the second sub-criteria. Applying the procedures described in the Appendix revealed the ranking of alternatives for public health considerations to be ***ECO>GAP>BAU~GM***.[3]

Rural Employment: To evaluate the alternatives only in terms of rural employment independent of any other economic and social concerns, their capacity to create jobs in rural areas was used as a measure, and the preference ranking was ***ECO>BAU>GAP>GM.***

The Economic Dimension

Farmers' Profits: There are three main determinants that affect the profits of an ordinary farmer (ΠF): price (per kg), cost (per hectares), and productivity (kg/hectares). By assessing the alternatives using studies on agricultural trends (Qaim, 2005; Brookes and Barfoot, 2009), collecting data and information from different sources (e.g. chambers of agriculture, farmer and expert interviews, FAO statistics [FAO, 2010]), and using expected productivity and input cost changes, the alternatives were ranked as $\Pi F_{GM} \geq \Pi F_{GAP} \geq \Pi F_{ECO} \geq \Pi F_{BAU}$.

Therefore, the preference ordering is ***GM>GAP>ECO>BAU***.

Input Providers' Profits: Input providers earn profit by selling either seeds or chemicals (pesticides and fertilizers). Thus, the surplus created by input provider firms may be expressed as $\Pi I = p \times q - c \times q$ where ΠI is their profit, p is input price (seed or chemical), c is the marginal cost of input, and q is input quantity.[4] Comparing the alternatives by their capacity to enable input providers to sell seeds and chemicals, the profit levels are ranked as $\Pi I_{GM} \geq \Pi I_{BAU} \geq \Pi I_{GAP} \geq \Pi I_{ECO}$ implying the preference ordering ***GM>BAU>GAP>ECO***.

Cotton Specific Current Account Deficit: The trade balances of the four alternatives were compared by taking different production quantities and export/import prices into account. Net export (NX) was calculated as $NX = QE \times PE - QI \times PI$, where QE is the quantity of exported cotton, PE is the price of exported cotton, QI is the quantity of imported cotton, and PI is the price of imported cotton. To decrease the trade deficit, it is necessary to increase $QE \times PE$ (the value of cotton exports) and/or decrease $QI \times PI$ (the value of cotton imports).Taking production trends and import and export figures for the last decade into account, relative NX performances of the different cotton production alternatives were found as $NX_{GAP} = NX_{GM} > NX_{BAU} > NX_{ECO}$, and hence, the cotton specific trade balance of the production alternatives were ranked as follows: ***GAP~GM>BAU>ECO***.

The Impact Matrix

Table 5 presents the ordinal impact matrix showing the performance of the GM cotton alternative with respect to the other three, evaluated for all criteria at the same time.

<<Table 5 About Here>>

As table 5 illustrates, each alternative has different economic, social, and environmental implications and there is no single alternative production method that performs best in all criteria, implying that there is no single scenario equally desirable to all stakeholders. Yet, one can still come up with an overall technical ranking of the alternatives by means of a mathematical algorithm.

Ranking the alternatives

The respective scores of the outranking matrix (e_{jk}) were calculated for each alternative by using the pair-wise comparison algorithm presented in the Appendix, and assigning equal weights (one-ninth) to all evaluation criteria; these are presented in table 6:

<<Table 6 About Here>>

The ranking procedure gives the following top five rankings presented in table 7 with highest φ_s scores among the 24 possible rankings.

<<Table 7 About Here>>

Table 7 suggests that the rankings ECO≻GM≻GAP≻BAU and ECO≻GAP≻GM≻BAU receive the highest scores after the aggregation process, implying the overall ranking of **ECO≻GM~GAP≻BAU**.[5] This ranking reflects that, as a benchmark, when all economic, social, and environmental criteria are considered equally important, the BAU alternative performs worse and the ECO performs best, while the GM and GAP methods do not outperform each other. One has to be careful, however, in drawing a fully optimistic picture for the ECO alternative. As revealed by the impact matrix (Table 5), the performance of the ECO alternative is very weak in the economic dimension; it performs the worst in input providers' profit and current account deficit, and ranks better than the BAU method only in farmer's profit.

Note that depending on the priorities, if different weights were given to different criteria, this ranking would change. If the focus and priority were just on the economic dimension, for instance, the GM alternative would overcome ECO. Therefore, the following section performs a sensitivity analysis by looking at the different weights that could be assigned to different criteria. Such an analysis is not only useful to better understand the positions of GM proponents and opponents, but also reveals the priorities of policy-makers, implicit in the decisions to approve or reject GM cotton.

Sensitivity Analysis to Criteria Weights

Table 8 below shows the sensitivity analysis applied to criteria weights and compares some extreme scenarios with the benchmark analysis by reporting the preferred ranking of alternatives with the highest φ_s score in each case.

<<Table 8 About Here>>

- When the economic dimension is disregarded (Scenario 1), the GM alternative's position deteriorates severely compared to the benchmark analysis: it ranks last. This underlines well that the GM alternative's strength heavily relies on the economic dimension.
- When no weight is assigned to the environmental dimension (Scenario 2), the ECO alternative loses the leading position it had in the benchmark analysis, but still performs as well as the GM, where both rank second to the GAP alternative. This shows that the strength of the ECO alternative is not only in the environmental dimension but also in the social one.

The BAU alternative again performs worst in this scenario, illustrating well that the problem with it is more than a bad environmental performance.

- In fact, the BAU alternative ranks either third or fourth in eight of these cases out of nine in total (including the benchmark), indicating that shifting cotton production to any of the other alternatives would indeed be a better strategy for Turkey than continuing with the status quo (BAU). Only when pure social interests are taken into account (Scenario 6), the BAU alternative ranks second after the ECO, explaining how the status quo in Turkey is sustained: thanks to its strength in the social dimension.
- When no weight is assigned to the social dimension (Scenario 3), the GM alternative outranks all others, emphasizing that the main weaknesses of the GM alternative are on the social dimension: in particular, with regard to uncertainty in biotechnology and concerns about GM over health impacts. This is not surprising since GM crops are mainly introduced for their potential economic and environmental advantages. Note also that in the case where only environmental dimension is prioritized (Scenario 5), the GM alternative ranks second to the ECO.
- When only economic concerns are considered (Scenario 4), the GM alternative ranks first and the ECO ranks last, falling even behind the BAU alternative. On the contrary, when only the social dimension is prioritized (Scenario 6), the ECO alternative ranks first and the GM ranks last. This comparison is helpful to see where the real tension among stakeholders lies in the GM debate.
- In an effort to represent the current tendency of policy-making in Turkey, more weights could be assigned to the economic dimension, followed by the social and environmental dimensions (Scenario 7). In this case, the GM alternative would outperform all others and the GAP alternative would perform better than the ECO.

Summary, Policy Implications, and Conclusions

Given the importance and complexity of the GM debate and conflicts of interest it generates, this paper employed the SMCE framework by constructing a multi-dimensional matrix that clearly shows the impacts of alternative cotton farming practices on economic, social, and environmental criteria that are expected to affect the GM approval decision by policy-makers. The SMCE exercise presented aimed at preparing the grounds for researchers, decision-makers, and the public to engage in a transparent discussion on GMOs that involves multiple and policy-relevant perspectives. The discussion below is significant for Turkey and can also be applied to other countries that are in the process of making similar policy decisions.

As reflected in the sensitivity analysis to criteria weights, this analysis showed that when only economic concerns were considered, the GM alternative ranked first and the ECO ranked last. On the contrary, when only the social dimension was prioritized, the ECO alternative ranked first and the GM ranked last. Hence, the tension in the GM cotton debate in Turkey, in line with the global GM dispute, emerges mainly between the conflicting interests in the social and economic dimensions. Unfortunately, when various conflicting dimensions are simultaneously considered, it is not possible to concurrently maximize all objectives since there is no alternative that ranks first in all criteria—creating the need for a compromise solution. The evaluation exercise in this paper signals that when only the economic and social dimensions are taken into account, the GAP alternative can be a neat compromise solution. Considering the status quo in Turkey, there is still much to do to improve current cotton farming methods and, in this sense, a shift from BAU to GAP will surely create less tension than a sudden shift from BAU to GM (or to ECO).

The current policy tendency in Turkey favors the economic dimension, in which case the GM alternative will outperform all others. In fact, if Turkey decides to approve GM crops, concerns against GMOs will most likely be raised in the social and environmental dimensions, and the country will face many policy challenges. First, technology-transcending aspects, such as market competition level and employment, and second, technology-inherent aspects of the health and environmental risks associated with the biotechnology will come forward as important points for discussion (see table 1 above). On the first point, new institutional approaches and governance mechanisms, such as public-private partnerships formed in several countries—especially in newly industrializing countries such as India and China (Cohen, 2005)—seem to be an option for Turkey as well. This partnership can make the newest technologies available to small farmers and tackle problems related to intellectual property rights (Karapinar and Temmerman, 2010). However, currently in Turkey, there is no attempt by governmental institutions to invest in GM seed development in cooperation with the private sector. Furthermore, a research attempt from the public side alone is also unlikely, since higher levels of investment in GMO research also requires strong political commitment (Karapinar and Temmerman, 2010), which Turkey currently lacks since the country imports the know-how of this technology and any other related regulations from abroad, the latter mostly from the EU. In terms of employment, the tendency of GM cotton farming to lower labor requirements and create rural unemployment (and related push factor migration) could be addressed by active welfare state policies.

On the second point, there are critical uncertainties in relation to "gene flow" and "public health" and the available policy tools are inadequate to solve these problems. In such situations, the general tendency of policy-makers is to rely on facts created by "sound science" (deemed objective and neutral) to reach a definitive answer (Alessandrini, 2010). Currently, this tendency is reflected in the GM debate as risk assessment studies by competent authorities such as the EFSA in the EU, and the FDA and EPA in the USA.[6] Turkey also seems to have adopted this approach, by establishing the Biosafety Council in 2010. However, two major problems still persist: the first is the assumption that science can construct "facts" in spite of ecological complexity and uncertainty, and ignorance of ignorance (Ravetz, 2004); and the second is the assumption that facts are isolated from values and interests conflicts, though they are in fact inherent in their construction (Latour and Woolgar, 1986; Alessandrini, 2010). The real problem in such situations is the lack of recognition of the multiplicity of values, and as Funtowicz and Ravetz (1994, p. 198) argue, the policy process should actually become "a dialogue … encompassing the multiplicity of legitimate perspective and commitments" by the democratization of knowledge and an extension of the peer community. The situation and policy-making on GM so far in Turkey seems to be far from this.

Finally, the primary objective of this evaluation exercise was not to suggest a specific policy decision to the government, but rather to provide policy-makers and researchers with a useful framework to understand the primary motives and decision mechanisms that underlie a policy decision, and also to discuss policy outcomes in the GMO context. Given that governmental decisions are affected by lobbies and power relations, it is very important to reveal which party benefits the most from a specific policy decision. Currently, the government is pressurized by seed companies and farmers' associations, which mainly represent big farmers, and by GMO opposition groups, such as NGOs and consumers. Hence, considering that the first group is likely to wield more lobbying power, it would not be wrong to say that the economic dimension may play a greater role in determining agricultural policies related to GM farming. It is also important to note that whatever the government decides, the decision will promote some groups in society, and bring costs to others. This analysis is helpful to understand such potential outcomes. Of course, in the end, this type of an exercise should be seen as a learning process in itself and never as a one-shot activity, and can be repeated periodically with new criteria that will reflect the priorities of the period in question.

APPENDIX

Let $G = \{g_m\}, m = 1,2, \dots, M$ be the set of criteria and $A = \{a_n\}, n = 1,2, \dots, N$ the set of alternatives, where it is assumed that each alternative a_n is evaluated based on an ordinal ranking with respect to an evaluation criterion g_m. A preference and an indifference relation between alternatives can be expressed as:

$$\begin{cases} P_{jk}: a_j P a_k \Leftrightarrow g_m(a_j) > g_m(a_k) \\ I_{jk}: a_j I a_k \Leftrightarrow g_m(a_j) = g_m(a_k) \end{cases};$$

where P is the preference and I is the indifference relation. Note that this representation suggests that a criterion score with a higher value is preferred to one with a lower value. (Of course, if the criterion is to be minimized, then, lower scores will be more favorable.) Here, both the preference and the indifference relations satisfy the transitivity property (if $a_i P a_k$ and $a_k P a_j$, then $a_i P a_j$). Next, to indicate the importance of criteria, a set of weights $W = \{w_m\}, m = 1,2, \dots, M$ is used with $\sum_{m=1}^{M} w_m = 1$. Once this set of information consisting of preference orderings and weights is obtained, the problem then becomes ranking the alternatives from best to worst in a complete pre-order, implying no incomparability relation. For this purpose, a two-step aggregation procedure is followed:

(i) *Pair-wise comparison of alternatives,* where an $N \times N$ *outranking matrix*, E (Arrow and Raynaud, 1986; Roy, 1996) is generated by obtaining each e_{jk} as elements of E, through pair-wise comparison of alternatives j and k, with respect to all the M criteria using the equation

$e_{jk} = \sum_{m=1}^{M} \left(w_m(P_{jk}) + \frac{1}{2} w_m(I_{jk}) \right)$.

Here, $w_m(P_{jk})$ are the weights of the preference, and $w_m(I_{jk})$ the weights of the indifference relation. Note that $e_{jk} + e_{kj} = 1$ and the outranking matrix E is formed by using $\mathrm{N(N-1)}$ pair-wise comparisons in total.

ii) Ranking the alternatives in a complete pre-order, where the maximum likelihood ranking of alternatives is used, which is the ranking supported by the maximum number of criteria for each pair-wise comparison, summed over all pairs of alternatives considered (a detailed rationale for the use and further explanation of this method can be found in Moulin, 1988; Munda, 2005; Gamboa and Munda, 2007). With N alternatives, it is possible to have N! rankings forming the set of all possible rankings, $\mathrm{R} = \{\mathrm{r_s}\}$, with $\mathrm{s} = 1,2, \dots, \mathrm{N!}$.

For each possible ranking r_s, the corresponding score φ_s is calculated as:

$$\varphi_s = \sum e_{jk},$$

with $j \neq k, s = 1,2, \dots, N!$ and $e_{jk} \in r_s$. The best technical ranking (r^*) is the one maximizing φ_s; therefore ,$r * \Leftrightarrow \varphi_* = \max \sum e_{jk}$, where $e_{jk} \in R$.

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[1] Technical details of the analysis can be provided by the authors upon request.
[2] where $\succ$ ($\sim$) represents the preference (indifference) relation.
[3] This ranking is in line with the ENTRANSFOOD project results (König et al., 2004) in the sense that GM farming has the same health impact as current farming practices, given that they are assessed with a relevant risk assessment approach.
[4] In the case of Turkey, most seeds and chemicals are imported, hence there are no significant fixed costs in the industry.
[5] The sensitivity analysis with regard to productivity assumptions used in farmers' profit calculations indicated that the final ranking is robust. For farmers' profits, the ranking changes from $\Pi F_{GM} \geq \Pi F_{GAP} \geq \Pi F_{ECO} \geq \Pi F_{BAU}$ to $\Pi F_{GM} \geq \Pi F_{GAP} \geq \Pi F_{BAU} \geq \Pi F_{ECO}$, where ECO is positioned last for all economic criteria. Even when this is the case, ECO still performs best in the overall ranking.
[6] EFSA: European Food Safety Agency; FDA: Food and Drug Administration; EPA: Environmental Protection Agency.

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Table 1: Potential Risks and Benefits of GM Crops

		Social Dimension	**Economic Dimension**	**Environmental Dimension**
BENEFITS	**Direct**		• Higher farm and industry level profits (due to lower input costs and potentially higher yields)	• Reduced release of chemicals to the environment
	Indirect	• Positive health effects by reducing farmers' exposure to toxic substances	• Convenience in labor management • Lower food prices due to increased supply	• Higher soil quality and less soil erosion thanks to conservation tillage • Less CO_2 emissions
RISKS	**Technology-Inherent** (Related directly to the technology)	• Food safety problems (Allergenicity, antibiotic resistance)	• Potentially high exposure to compensation liability (in case of health and environmental damage) • Economic risks associated with brand value and image	• Unintended gene flow • Development of pesticide resistant weeds and insects • Risks for non-target organisms

Technology-Transcending (Related to the use of the technology)	• Distributional problems related to the monopolization of the seed market • Increased gap between rich and poor • Intellectual property rights problems		• Biodiversity loss (through monoculture practices)

Prepared by reference to Altieri and Rosset (1999); McGloughlin, (1999); Shiva (2001); Nelson and De Pinto (2001); Persley and Siedow (2002); Qaim (2005); Frisvold et al., (2006); Murugkar et al., (2007); Ervin et al., (2010*);* James(2011); Brookes and Barfoot (2011); and Dannenberg et al., (2011).

Table 2: Cotton Farming Alternatives and Their Degrees of Intensification

	Degree of Intensification	Site Preparation	Germplasm (Seed)	Nutrients	Pest Control	Harvesting
ECO	Very Low	Manual and mechanized	Crop and cultivar selection (organic seed)	Fallowing, legumes, organic manure	Using natural enemies, traps, manual weed removal	Manual
BAU	Moderate	Fully mechanized	Cultivar selection (conventionally bred seed)	Extensive use of mineral fertilizers	Extensive use of pesticides, manual weed removal	Manual/ Mechanized
GAP	High	Conservation tillage/ Minimum tillage	Cultivar selection (conventionally bred seed)	Efficient use of mineral + organic fertilizers	IPM with less risky chemicals	Mechanized
GM	Very High	Conservation tillage/ Minimum tillage / No tillage	Cultivar selection (genetically engineered seed)	Efficient use of mineral + organic fertilizers	IPM with less risky chemicals and refuge zones / Pest and chemical resistant Crops	Mechanized

Table 3: Evaluation Criteria

	Criterion	Definition and Importance	Needs And Expectations
Environmental	Agro-Biodiversity	Farming activities alter the environment and reduce biodiversity either by producing wastes that pollute the soil, water, and air, or by destroying wild habitat (Srivastava et al., 1996). Therefore, all farming activities should respect biological and cultural habitats (Brookfield and Stocking, 1999).	Maximize both the number of and variations within plant and animal species. Preserve the cultural habitat of indigenous farmers.
	Unintended Gene Flow Potential	Since transgene flow may have irreversible long-term effects for nature, agricultural practices should lead to minimum unintended gene flow (Wolfenbarger and Phifer, 2000; Snow and Lu, 2005).	Prevent gene flow from GM products to non-GM products.
	Greenhouse Gas (GHG) Emissions	Given that the amount of GHG emissions created by agricultural machinery and inputs contribute significantly to climate change (Lal, 2004), a preferable agricultural practice should minimize GHG emissions.	Reduce GHG emissions.
Social	Level of Competition in the Input Market	While a competitive agricultural input market structure provides socially efficient outcomes, a highly concentrated market creates major disadvantages for both farmers and society; furthermore, small farmers are subject to monopoly prices, and hence become dependent on multinational companies (Murugkar et al., 2007). Therefore, all farming activities should promote increased market competition.	Prevent the monopoly/oligopoly structure of input markets. Reduce farmer dependency on input providers.
	Public Health Considerations	Since cotton seeds are both a major source of oil (for industrial food production) and animal feed, cotton production has an indirect effect on public health. Hence, any agricultural practice should minimize the adverse (and uncertain) health effects created by chemical input use and gene transfer.	Prevent allergenic reactions caused by gene transfer and chemical use. Reduce the carcinogenic effects of chemical use by using less toxic chemicals or decreasing the amount of chemicals.
	Rural Employment Level	Given the pressure of rural to urban immigration in Turkey, keeping the rural labor force in agriculture is important. Hence, agricultural practices that create as many employment opportunities as possible in rural areas are desirable.	Prevent rural to urban migration resulting from rural unemployment acting as a push factor.
Economic	Farmers' Profits	Desirable farming practices should maximize profits in all areas to boost farmers' gains.	Decrease farmers' input costs. Increase farm productivity. Increase farm gate prices.
	Input Providers' Profits	Ranging from a single farmer firm to a giant multinational corporation, an input provider is an entity capable of delivering agricultural inputs and supplements. Considering that increasing input providers' profits promotes economic welfare of the society, desirable agricultural practices should generate higher profits for input providers.	Increase profits of the input (seed and chemicals) providing firms.
	Cotton Specific Current Account Deficit	Despite its significant cotton production capacity, Turkey's cotton production does not match the needs of its large textile industry, making it a net importer of cotton and implying a current account (CA) deficit. Since keeping the CA deficit at a low level is important in particular for developing countries, desirable agricultural production practices should lead to lower levels of CA deficit.	Minimize the trade deficit related to the cotton trade.

Table 4: Impact Matrix for Agro-biodiversity

Sub-criteria (All to be minimized)	ECO	BAU	GAP	GM
EIQ of Chemicals Used	First	Fourth	Third	Second
Area of Land Used for Unit Production	Third	Second	First	First
Loss of Genetic Variation within Species	First	Third	Third	Second
Loss of Indigenous Knowledge	First	Third	Second	Fourth

Table 5: Impact Matrix

			ECO	BAU	GAP	GM
Criteria	Environmental	***Agro-biodiversity***	First	Fourth	Third	Second
		Unintended Gene Flow Potential	First	First	First	Second
		GHG Emission	First	Fourth	Third	Second
	Social	***Level of Competition in Input Market***	First	Third	Second	Fourth
		Public Health Considerations	First	Third	Second	Third
		Rural Employment Level	First	Second	Third	Fourth
	Economic	***Farmers' Profits***	Third	Fourth	Second	First
		Input Providers' Profits	Fourth	Second	Third	First
		Cotton Specific Current Account Deficit	Third	Second	First	First

Table 6: Outranking Matrix

j \ k	**ECO**	**BAU**	**GAP**	**GM**
ECO	0	0.72	0.61	0.67
BAU	0.28	0	0.28	0.39
GAP	0.39	0.72	0	0.5
GM	0.33	0.61	0.5	0

(e_{jk} score means alternative j outranks alternative k in e_{jk}/w_m criteria in total, where w_m is the criterion weight. In this specific case, there are nine equally-weighted criteria, where $w_m = 1/9$. Hence, for instance, $e_{GM,ECO} = 0.33$ means in the pair-wise comparison, GM outranks ECO in three criteria. Note that $e_{jk} + e_{kj} = 1$ for all j, k.)

Table 7: Rankings with the Highest φ_s Scores

#	Ranking	φ_s Score
1	ECO≻GM≻GAP≻BAU	3.83
1	ECO≻GAP≻GM≻BAU	3.83
3	ECO≻GAP≻BAU≻GM	3.61
3	GAP≻ECO≻GM≻BAU	3.61
5	GM≻ECO≻GAP≻BAU	3.50

Table 8: Sensitivity Analysis to Criteria Weights

		Benchmark Analysis	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
			No Economic Priority	**No Environmental Priority**	**No Social Priority**	**Pure Economic Priority**	**Pure Environmental Priority**	**Pure Social Priority**	**Current Policy Tendency**
	CRITERIA	**Weights**	**Weights**	**Weights**	**Weights**	**Weights**	**Weights**	**Weights**	**Weights**
Environmental	***Agro-biodiversity***	1/9	1/6	0	1/6	0	1/3	0	1/18
	Unintended Gene Flow Potential	1/9	1/6	0	1/6	0	1/3	0	1/18
	GHG Emission	1/9	1/6	0	1/6	0	1/3	0	1/18
Social	***Level of Competition in Input Market***	1/9	1/6	1/6	0	0	0	1/3	1/9
	Public Health Considerations	1/9	1/6	1/6	0	0	0	1/3	1/9
	Rural Employment Level	1/9	1/6	1/6	0	0	0	1/3	1/9
Economic	***Farmers' Profits***	1/9	0	1/6	1/6	1/3	0	0	1/6
	Input Providers' Profits	1/9	0	1/6	1/6	1/3	0	0	1/6
	Cotton Specific Current Account Deficit	1/9	0	1/6	1/6	1/3	0	0	1/6
	WINNING RANKING (Highest φ_s score)	**ECO>GM~GAP>BAU**	**ECO>GAP>BAU>GM**	**GAP>ECO~GM>BAU**	**GM>ECO>GAP>BAU**	**GM>GAP>BAU>ECO**	**ECO>GM>GAP>BAU**	**ECO>BAU>GAP>GM**	**GM>GAP>ECO>BAU**