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Review

Measuring the effect of climate change on agriculture: A literature review of analytical models

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This article provides a short overview of the principal models that can be used to estimate the effects of climate change on agriculture. The models are classified in relation to the following criteria: the specific impacts they aim to assess, their ability to measure production and/or economic losses, and the adoption of social indicators of the effects and responses. The weaknesses and strengths of the models are also identified and discussed. The most relevant factors for the choice of the most appropriate model are analysed. Through a comparative analysis of the literature, an easily adoptable scheme for selecting the most appropriate method to estimate the effects of climate change according to the characteristics of the case study is identified. The adopted classification scheme demonstrates that one model is capable of simultaneously considering many aspects related to climate change and classifying these in different class.

Key words: Climate change, impacts, agriculture, models.

JEL Classification: C50, Q15, Q51.

INTRODUCTION

Agriculture is one of the sectors most affected by ongoing climate change. The wide range of literature on this subject demonstrates that damages caused by climate change can be relevant to both cropping and livestock activities (IPCC, 1990; Adams et al., 1998). Climate change will have a significant effect on the rural landscape and the equilibrium of agrarian and forest ecosystems (Walker and Steffen, 1997; Bruijnzeel, 2004). In fact, climate change can affect different agricultural dimensions, causing losses in productivity, profitability and employment. Food security is clearly threatened by climate change (Sanchez, 2000; Siwar et al., 2013), due to the instability of crop production, and induced changes in markets, food prices and supply chain infrastructure. Moreover, because of the multiple socio-economic and bio-physical factors affecting food systems and, consequently food security, the capacity to adapt food systems to reduce their vulnerability to climate change is not uniform from a spatial point of view (Gregory et al., 2005).

However, besides its primary role in producing food and fibres, agriculture performs also other functions, such as the management of renewable natural resources, the construction and protection of landscape, the conservation of biodiversity, and the contribution to maintain socio-economic activities in marginal and rural areas. Climate change could affects also this multifunctional role of agriculture (Klein et al., 2013).

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The ongoing effects of climate change require the individuation of mitigation policies to reduce greenhouse gas emissions and identify appropriated adaptation strategies that aim to contain agricultural losses both in market goods and environmental services (such as protection of biodiversity, water management, landscape preservation and so on). These strategies can easily be identified and applied if the economic effects of climate change on agriculture are assessed. However, creating models that are able to assess these effects accurately can present difficulties for several reasons. The first is data availability: while data are frequently available, they are often not disaggregated on the necessary temporal and/or spatial scales. Another reason is that research about the effects of climate change involves multidisciplinary skills and competencies because analyses of the effects of climate change involve many factors such as the consideration of (Bosello and Zang, 2005):

1. Climate and other induced climate-change environmental aspects,
2. Biological and plant physiology aspects,
3. Technical and socioeconomic factors,
4. Strategies to coping with the effects of climate change,
5. Impacts on/of the main economic adjustment mechanisms at the national and international level,
6. Feedback of the changed conditions on climate.

Economic and agricultural policies play an important role in such analyses, as does the geographical scale (e.g. local, regional or international) considered for the analysis. In addition to these aspects, it is also important to consider the temporal and spatial variability of the events which in turn causes a difficult predictability of future scenarios.

Considering all these aspects simultaneously is problematic. For this reason the literature proposes several models that are suitable for estimating the effects of climate change on agriculture addressing specific research issues. In light of this the present article offers an overview of the models most used to estimate the effects of climate change on agriculture (section 2) aimed to classify these models and to propose a logical scheme to help researchers in the selection of the model that best suits their research goals (section 3). The fourth section presents the conclusions.

LITERATURE REVIEW

The literature suggests that various models can be employed to assess the effects of climate change on agriculture. Each model has advantages and shortcomings, and presents different levels of complexity and completeness in relation to the specific aspects considered in its analysis. These peculiarities are discussed below for each models category.

The effects of climate change were evaluated by several scholars with consideration given only to the changes in the production of specific crops (principally maize, rice, cotton and soybean), using the so-called ‘crop simulation models’. These models restrict the analysis to crop physiology, and simulate and compare crop productivity for different climatic conditions (Eitzinger et al., 2003; Torriani et al., 2007a). Crop models are considered ‘agriculture oriented’ because the analysis of these models is focused on the biological and ecological consequences of climate change on crops and soil. In these models, farmers’ behaviour is not captured and the management practice is considered fixed. Moreover, they are crop and site specific, and they were calibrated only for the major grains and for a limited number of places (Mendelsohn and Dinar, 2009).

Others scholars estimated the sensitivity of yields to climate using empirical yield models that apply the production–function approach (Terjung et al., 1984; Eitzinger et al., 2001; Isik and Devadoss, 2006; Lhomme et al., 2009; Poudel and Kotani, 2013). The basic idea of this approach is that the growth of agricultural production depends on soil-related and climatic variables that are implemented as explanatory variables in the model for estimating the production function. Changes in climate scenarios are usually simulated using the general circulation model (GCM) (Chang, 1977; Randall, 2000).

In the production function approach, the economic dimension is of secondary importance and is considered in a partial and simplified manner (Bosello and Zang, 2005), even if these models produce important information for larger model frameworks that consider economy, later discussed. Some studies explicitly assess the economic impact of climate change through the estimation of the economic production function (Adams, 1989; Rosenzweig and Parry, 1994). However, other research evaluates the economic effects of climate change by implementing the results of agronomic analyses or of empirical yields models in mathematical-programming models (Kaiser et al., 1993; Finger and Schmid, 2007).

The main weakness of the production–function model is that it is crop and site specific. It endorses the so-called ‘dumb-farmer’ hypothesis, which excludes from analysis the plausible adoption by farmers of strategies for coping with the effects of climate change, for example, strategies that replace crops that are most sensitive with others that are less so (Rosenzweig et al., 1993; Reilly et al., 1994).

To overcome this limitation, Mendelsohn et al. (1994) proposed the Ricardian model. The principal characteristic of the Ricardian model is that it treats adaptation to climate change as a ‘black box’. In fact it estimates the relationship between the outcomes of farms and climate normals using cross-sectional data and including, among regressors, appropriate control variables. As such, it implicitly considers farmer adaptation strategies without the need to implement such strategies as explicit exploratory variables (Mendelsohn and Dinar, 2009).

However, this aspect could also represent a weakness in the model if the aim of the analysis were to estimate the effect of farmer adaptation strategies on climate change. Due to this weakness in analysis, models have been proposed that use mathematical programming to consider specifically farmer adaptation strategies (Adams et al., 1990; Kaiser et al., 1993; Mount and Li, 1994), especially concerning irrigation (Medellín-Azuara et al., 2010). However, these applications often suffer the limitation of considering hypothesised and simulated strategies that can be derived by incorrect simulation of the farmers' goal function.

The latest applications of the mathematical-programming model use positive mathematical programming (PMP) (Qureshi et al., 2010, 2013; Howitt et al., 2012). These surpass the traditional limitations of linear-programming methods, for example, the unavailability of detailed information about the relationship between inputs and yields through the function cost. In the field of the assessment of climate change impacts on agriculture this model is particularly suitable for analysis of the effects of drought on agriculture because it allows different aspects related to the use and availability of water to be explicitly treated. However, given that this model needs to consider data that can be difficult to collect (e.g. water cost by considering the source of water, the water requirements of crops, and the availability of water resources), its applicability is also limited.

More recently, other research has attempted to overcome the limitations of the Ricardian model in considering farmer adaptation strategies[1] by using econometric models estimated on farm survey data. These applications explicitly treat farmer adaptation strategies by using their proxies as explanatory variables (Di Falco and Veronesi, 2013a, b; Oluwasusi, 2013) or by modelling adaptation as the dependent variable (Gebrehiwot and Van Der Veen, 2013). These applications have the advantage of being able to estimate using the available data.

Moreover, they are suitable to be specified through sophisticated models that can consider specific characteristics of the database such as endogeneity, stratified samples, spatial correlation, and panel and time-series data. With such applications, it is also possible to hypothesise different equation functional forms (e.g. linear, log-linear, quadratic, Box Cox) as well as different distributions for the error term (e.g. normal, Weibull, probit, logit) while at the same time, using the most suitable estimator (e.g. ordinary least squares, maximum likelihood estimator) according to the specific model. However, the predictive ability is strongly connected with the accuracy of the model specification and the data quality. On this last aspect impacts the impossibility to consider strategies that are new. In fact in the past we did not have climate change so in the future new approaches need to be developed.

All the models that have been discussed focus on the agricultural sector, its specific branches, or crops without considering the relationships with other economic sectors. For this reason, further research developed general equilibrium economic models (GEMs) (Darwin et al., 1995; Borsello and Zang, 2005; Calzadilla et al., 2010a, b). GEMs examine the economy as a complex system composed of interdependent components (e.g. industry, factors of production, institutions and international economic conditions). GEMs have the advantages: to capture economy-wide and global changes, and to measure the effects of climate change on other economic sectors. Conversely, they are limited in that they aggregate in a single entity different sector characterised by specific economic and spatial dimensions. For example, agriculture is generally considered as an aggregate sector at the national level without considering its local specificities. Similarly, production factors (including irrigation water) are implemented in the model as undifferentiated commodities. Further, GEMs do not consider farmer adaptation to climate change or all dimensions, skills, and competencies that should be involved in the analysis of the effects of climate change (Mendelsohn and Dinar, 2009).

Consequently, researchers developed integrated assessment models (IAMs)[2] that combine the use of GCM with data on crop growing, soil usage, and economic models (Prinn et al., 1999; Kainuma et al., 2003). IAMs describe the causes and effects of climate change, integrating knowledge from different academic disciplines into a single framework to generate useful information for policymakers (Dinar and Mendelsohn, 2011).

The integration of such varied skills and disciplines means IAMs are often particularly complex. Moreover, interactions between agriculture and land usage with climate are only partially treatable in such models and the accuracy of this model is subject to the treatment of complex interactions (e.g. the availability and the competitive use of water between economic sectors). Another limitation is that productivity is treated as an exogenous variable, even if it is strongly correlated with the climate (Dinar and Mendelsohn, 2011). Tables 1 and 2 summarises the advantages and limitations for each of the models that have been discussed in the literature review.

[1] Seo and Mendelsohn (2008) propone a multiple-stage model called the structural Ricardian model that first estimates an adaptation model on farmer choice, and then estimates the conditional income for each choice using a traditional Ricardian formulation.

[2] For more information on IAMs, see: IMAGE (http://www.mnp.nl/en/themasites/image/index.html) or IGSM-MIT (http://globalchange.mit.edu/igsm/).

Table 1. Principal models used to estimate the effects of climate change on agriculture.

Model	Brief description	Advantages	Limitations
Crop simulation	This model restricts the analysis to crop physiology, and simulate and compare crop productivity for different climatic conditions	It is based on a deep understanding of agronomic science It is suitable to integrate effects of carbon dioxide fertilization It is calibrated to local condition	Analysis is focused on the biological and ecological consequences of climate change on crops and soil Economic dimensions are not considered. This model can be coupled with other models to better treat economic dimension. In the traditional formulation adaptation is not considered and the farmer's management practice is considered fixed. Some researchers consider adaptation exogenously. It do not consider crop's switching. It is crop and site specific It was calibrated for the main grains and for a limited number of places
Production Function	Yields sensitivity to climate is estimated assessing a empirical production function that links water, soil, climate and economic input to yields for specific crops.The effect of climate change is assessed by considering yield variations comparing two alternative scenarios. Future climate scenarios are usually simulated using a GCM.	Easy to estimate It is possible to measure the effect of weather on yields over time	Crop specific Social and economic dimensions of agriculture are considered of secondary importance. This model can be coupled with other models to better treat economic dimension. Assumption of the 'dumb-farmer' hypothesis (farmer adaptation strategies are not considered) Calibrated for a specific context; if the location is not representative, can provide biased predictions.
Ricardian	This model treats the full range of farmer adaptation strategies as a black box by performing a cross-sectional regression of land values or net revenues on climate normals and other control variables. Climate normals are calculated as averages in a long-term scenario (usually 30 years). The effects of climate change are assessed in terms of farm outcome variations, comparing the current situation to simulated scenarios.	Does not assume the 'dumb-farmer' hypothesis Easy to estimate Possible to consider spatial correlations and to analyse panel data Possible to elicit farmer adaptation in estimation if a multinomial logit model (e.g. a structural Ricardian model) is used.	Omitted variables, such as unobservable farm and farmer characteristics could lead to bias of unknown sign and magnitude In the traditional formulation, farmer adaptation strategies are considered but not explicitly treated In the traditional formulation, the role of irrigation is not considered. More recently, this variable was included among the regressors. However, it is not treated endogenously and multicollinearity problems are not adequately considered Analysis is focused on the economic dimension of agriculture and only indirectly on other dimensions (e.g. biological and social) Assumes a partial equilibrium model and does not consider relationships with other sectors Assumesthe output and input prices constancy and does not measure adjustment costs.

Table 1. Contd.

PMP	This is an economic management model estimated by solving a mathematical-optimisation problem using farm data. The pay-off function can be formulated considering the profit (to be maximised) or the cost (to be minimised). The latter, known as the Positive Mathematical Programming, surpasses the traditional limitations of linear-programming methods such as the unavailability of detailed information on the relationships between inputs and yields through the dual function cost.	Useful for assessing the economic effects of climate change, especially in the simulation of irrigation-farmer adaptation options and/or water policies, including water markets and irrigation efficiency improvement.	Difficult to estimate Often difficult to find data on technical coefficients and limiting production factors Assumes simulated farmer strategies not obtained from observed choices in specific climatic scenarios.
GEM	These look at the economy as a complex of interdependent components (e.g. industry, production factors, institutions).	Assumes a general economic equilibrium, considering all economic sectors Captures economy-wide and global changes such as those linked to input and output prices Provides information on the effect of climate change in different regions Measures the effect of climate change on other economic sectors.	Difficult to estimate Aggregates into one single entity sectors that are different in economic and spatial characteristics Production factors, including irrigation water, are considered in the model as undifferentiated inputs Difficult to analyse farmeradaptation strategies Doesnot allow consideration of details of the studied phenomena.
IAM	These are based on the joint use of General Circulation Model, crop growing, soil usage, and economic models. These models integrate different skills and competencies.	Analysis simultaneously considers all agricultural dimensions Generates useful information for policymakers.	Difficult to estimate These models can be very complex In some cases the required data are not available Interaction between agriculture and land use with the climate are only partially treatable Accuracy of model is subject to the treatment of the complex interaction between different factors, especially concerning water usage and availability Productivity is treated as an exogenous variable.

CLASSIFICATION OF MODELS, RESEARCH QUESTIONS TO BE ANSWERED, AND CRITERIA FOR CHOOSING THE MOST SUITABLE MODEL

To assess the effect of climate change on agriculture, the choice of the most appropriate model depends on the following factors:

1. The level at which the analysis needs to be conducted—this could be the agricultural sector; whole, or one crop, or a particular agricultural branch[3]
2. The (temporal or spatial) scale of analysis; as a

[3] The literature discusses numerous applications that estimate the effect of climate change on permanent cultivations (Lobell et al., 2006), viticulture (Tate,

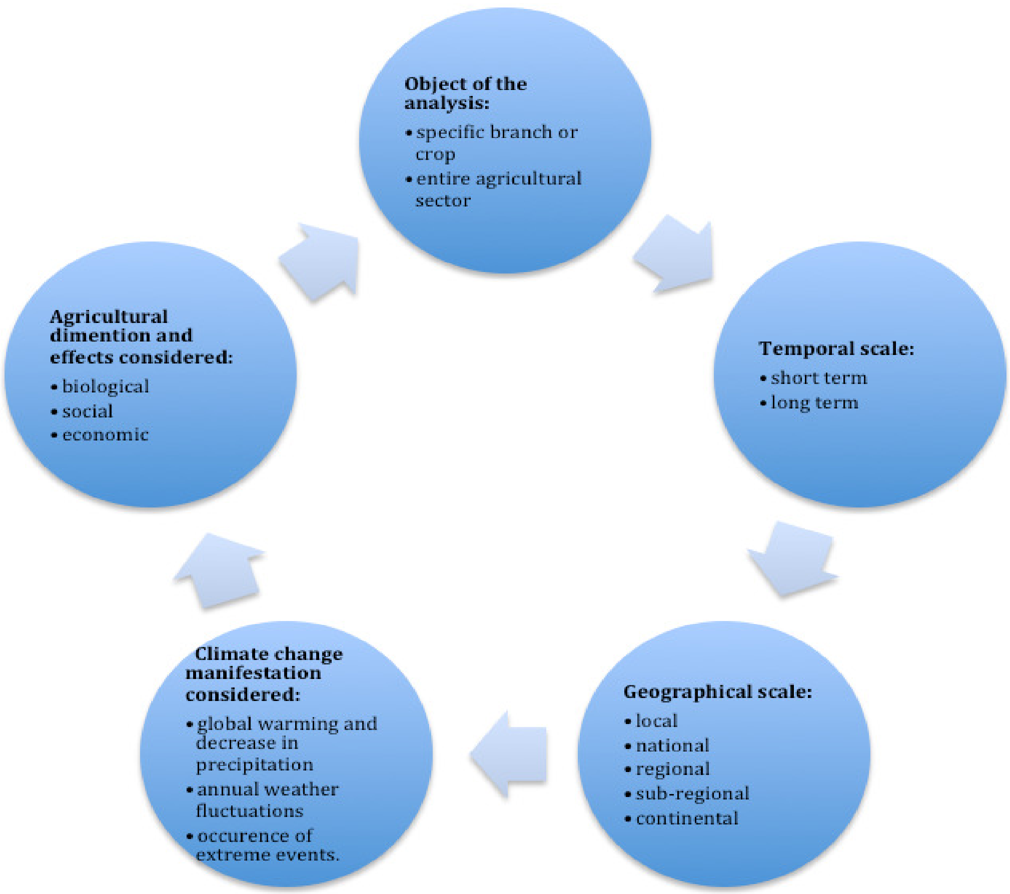

Figure 1. Aspects that influence the choice of model to be used; Source: Authors' elaborations.

whole, or one crop, or a particular agricultural branch[4];
3. The climatic phenomenon used to measure the analysed climate change (Tate, 2001; Bernetti et al., 2012), and livestock (Seo, 2008; Reynolds et al., 2010; Kimaro and Chibinga, 2013);
4. The agricultural dimension (biological, social or economic) with respect to which climate change impacts are assessed.

Figure 1 summarises the hierarchical links between these elements. The first aspect (the level of the analysis) and the fourth aspect (the agricultural dimension to be considered for estimating the effects of climate change) are connected. In fact, the models devoted to the analysis of the biological dimension of agriculture are crop specific; consequently, they concern only a single crop or branch. Conversely, the models devoted to assessing the effect of climate change on the social or economic dimensions of agriculture can consider the agricultural sector as a whole or one of its branches.

In reference to the scale of analysis it can concern cross-sectional, panel, or time-series data. In the latter case the length of the time period to be considered depends on the analysed scenario. The spatial scale can be very significant when the empirical evidence demonstrates that the magnitude of the effect of climate change varies significantly according to the location and the size of the areas studied. Previous research has highlighted that agriculture in warmer areas is more affected by climate change than agriculture in colder areas (Mendelsohn et al., 1994; Schlenker et al., 2005). However, the effects can vary dramatically on international, national and local scale (Bindi and Olesen, 2011). This variation in the effects is due to differences in adaptation strategies, which correlate highly with the local cultural, institutional and environmental conditions.

Another important issue to be considered is the specific manifestation of climate change that the model considers in calculating its effect on agriculture. This issue may concern:

1. A general increase in temperatures, accompanied by a decrease in precipitations characterising a long-term scenario (climate warming and precipitations change);

[4] The literature discusses numerous applications that estimate the effect of climate change on permanent cultivations (Lobell et al., 2006), viticulture (Tate,

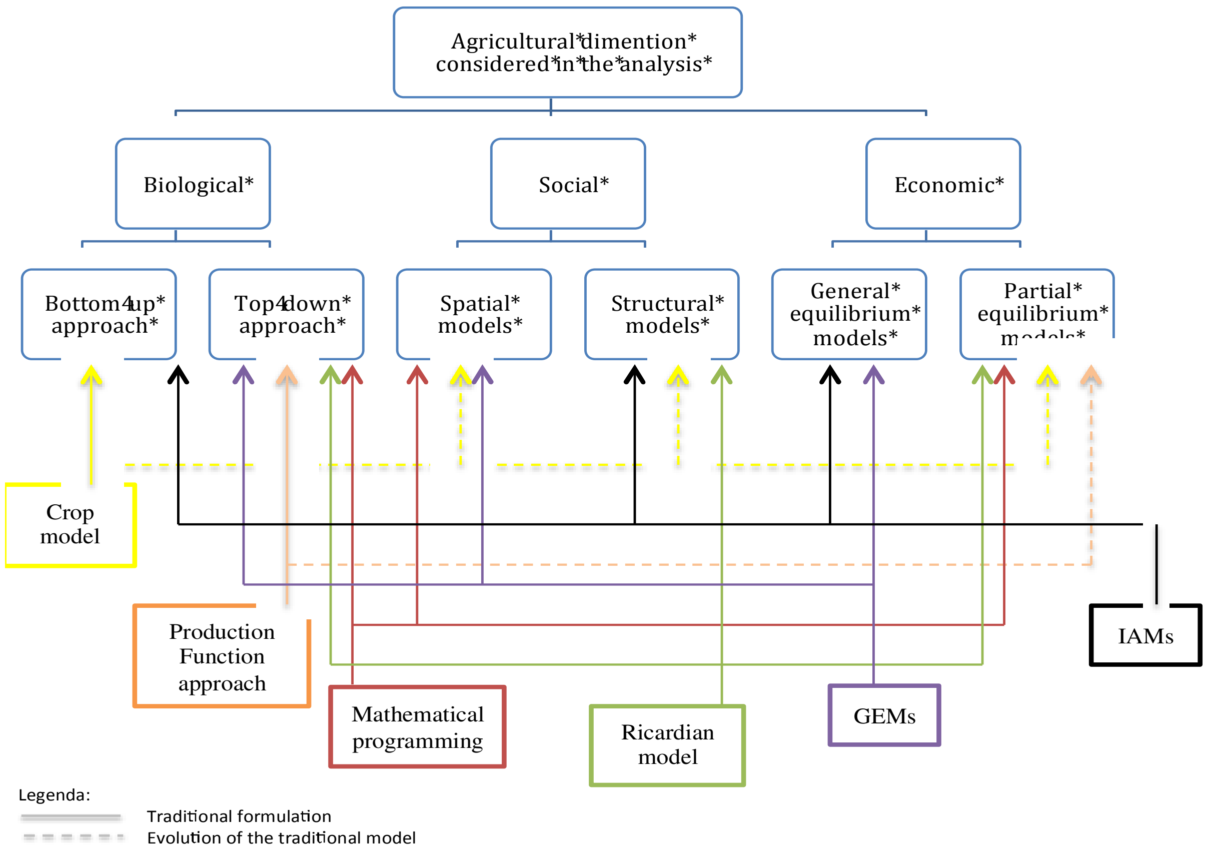

Figure 2. Classification of models by agricultural dimension, Legend: Traditional formulation; Evolution of the traditional model; Source: Authors' elaborations.

2. Annual fluctuations in the weather in terms of temperature and precipitations;
3. The frequency of extreme weather events such as droughts or floods.

Each of these aspects plays a different role and causes different effects on agriculture. The issue that has been the subject of most research is the effect of climate change in a long-term scenario. This has been widely analysed using the Ricardian model. The other two forms of the effects of climate change have been less investigated. Annual fluctuations in the weather were examined by Kelly et al. (2005) and Deschenes and Kolstad (2011). The effects of drought were analysed by Trnka et al. (2010, 2011) and of cyclones by Dasgupta et al. (2011). Figure 2 presents a classification of models that consider the biological, social, and economic dimensions of agriculture.

As demonstrated in Figure 2, if the focus is on the effects in terms of production change, by considering the biological aspects and their dynamics, it is possible to implement plant-physiology models that correlate the production output to climate variables or vegetation distribution behaviours. As such, it is possible to explain the spatial distribution of crops in relation to the climate scenario. In this case the model adopted is a bottom-up model (Bosello and Zang, 2005). Alternatively, it is possible to use a top-down model (or spatial analogue), which analyses crop reaction to climate change based on the productivity values in different temporal and spatial scenarios.

Further, in the assessment of the social effects, it is possible to distinguish spatial versus structural models (Bosello and Zang, 2005). Through the analysis of choices, strategies, and technologies used in different climatic and geographic scenarios, both of these models provide the possibility of forecasting behaviours will be adopted by farmers to face climate change.

Spatial models analyse variations in a farm's performance when dealing with climate change without considering farmer adaptation. This type of model hypothesises that such variations do not affect the prices of agricultural commodities and inputs. Consequently, this model does not consider the effects of climate change on agricultural demand and supply. Moreover, spatial models implicitly assume the absence of progressive farmer adaptation processes through changes in production cost in the short-term and medium-term scenarios. It follows that it is not possible to differentiate climate-change adaptations endorsed by the

Table 2. Characteristics demonstrated by the most commonly used models to assess the effects of climate change on agriculture.

Model	Object of the analysis	Temporal scale	Geographical scale	Climate change manifestation	Agricultural dimension			References
					Biological	Social	Economic	
Crop simulation	A specific crop	Short time	Local	Weather annual fluctuation	Treated	Not treated in the traditional formulation. It is possible to treat it exogenously.	Not treated in the traditional formulation. However it is possible to couple this model with larger model frameworks that consider economy.	Eitzinger et al. (2003), Torriani et al. (2007)
Production function	A specific crop, a group of crops or a particular ecosystem	Both short term and long term	All possibilities	All possibilities	Not explicitly treated	Treated in a secondary manner.	In the traditional formulationtreated in a secondary manner. Some studies estimate and economic production function. Others couple this model with larger model frameworks that consider economy.	Terjung et al. (1984), Isik and Devadoss (2006), Poudel and Kotani (2013)
Ricardian	The whole agricultural sector or a particular branch or crop	Long term	All levels, providing enough climatic variability is assured	Global warming and precipitations decreasing	Not explicitly treated	Not explicitly treated in the traditional formulation but explicitly treated in the structural Ricardian model	Treated	Mendelsohn et al. (1994), Schlenker et al. (2005), Seo and Mendelsohn (2008), De Salvo et al. (2013), Massetti and Mendelsohn (2011)
Econometric model	The whole agricultural sector or a particular branch or crop	Both short term and long term	All levels, especially local, national or regional	All possibilities	This depends on the model formulation	This depends on the model formulation	This depends on the model formulation	Schlenker and Roberts (2006), Deschênes and Greenstone (2007), Di Falco and Veronesi (2013a, b).
PMP	The whole agricultural sector or a particular branch	Both short term and long term	All levels, especially local, national or regional	All possibilities	Not explicitly treated in the traditional formulation. Some researchers treat it explicitly coupling this model with a crop simulation model	Treated	Treated	Quresh et al. (2010), Howitt et al. (2012), Qureshi et al. (2013)

Table 2. Contd.

GEMs	The whole agricultural sector or a particular branch if appropriately formulated	Long term	All levels, especially national or higher	All possibilities	Not explicitly treated	Not explicitly treated	Treated	Darwin et al. (1995), Calzadilla et al. (2010a, b), Trnka et al. (2010, 2011)
IAMs	The whole agricultural sector or a particular branch if appropriately formulated	Long term	All levels, especially national or higher	Global warming and precipitations decreasing	Treated	Treated	Treated	Prinn et al. (1999), Kainuma et al. (2003)

agricultural sector from those deployed by the economy as a whole, and neither is it possible to separate these adaptations from those put in place to deal with factors other than climate change (Molua and Lambi, 2007).

The structural models through which the physical, social, and economic responses of agriculture to climate change are analysed overcome these limits. However, the application of these models is sometimes hampered by a need for detailed information on business-management practices.

By focusing only on the economic dimension, applicable models can consider a partial equilibrium or a general equilibrium in sectorial and/or geographical terms. GEMs, or economy-wide models, were used to estimate the economic effect of climate change on agriculture (e.g. Darwin et al., 1995; Borsello and Zang, 2005; Calzadilla et al., 2010a, b). These applications look at the whole economy and consider the relationships between sectors. However, they present some limitations (Table 1) that are overcome by the partial equilibrium models, which focus on a part of the economic system, consisting of a single market or a set of markets or sectors (Deressa, 2007).

The microeconomic partial equilibrium models can omit important aspects of the issue being considered, for example:

1. The re-allocation of production factors,
2. Changes in demand for agricultural products,
3. The interrelation of the economic sectors,
4. The dynamics of international markets,
5. The endogenous nature of market prices for agricultural products and inputs.

Moreover, the partial microeconomic equilibrium models can be divided into two broad categories: models based on the simulation of the crop-growth processes (crop-growth simulation models) and econometric methods (Kurukulasuriya and Rosenthal, 2003; Deressa, 2007) that also include the widely used Ricardian models. The choice of the best model to assess economic effects depends heavily on the specific aspects that the analysis has to consider and on the level of detail (Table 2).

Conclusion

The assessment of the effects of climate change on agriculture and the choice of the model that better suite the research aims remains a complex area for several reasons. First, data are not always available and/or disaggregated on the necessary temporal or spatial scales. Second, such research involves different skills and professional competencies, which means that analyses have to consider biological and physiological aspects; technical and socioeconomic features; and adaptation strategies adopted by farmers and breeders to face climate change. Third, a relevant role is played by aspects related to economic and agricultural policies and to the geographical (local, regional or international) scale of the analysis. Finally, a valid model should consider the temporal and spatial variability of climate; the uncertainty of future climate scenarios;

and the feedback of agricultural changes due to climate change.

Consequently, the selection of the most appropriate model should consider different aspects of the research problem, for example:

1. The specific object of the analysis,
2. The temporal and geographical scales,
3. The specific forms of climate change that are being considered (e.g. climate warming, weather fluctuations or extreme climatic events),
4. The magnitude of the effects expressed according to the agricultural dimensions (biological, social and/or economic) that the analysis aims to consider.

The choice of the model to be implemented is one of the most important steps in a assessment project. In the analysis of the effects of climate change on agriculture, the literature offers a multitude of applicable methods and tools, each of them with specific advantages and disadvantages. Consequently, the choice of the best model can be difficult due to a lack of perfect knowledge of all the possible alternatives. The choice of the model to apply for analysis often follows the trend of the moment, and is applied without detailed analysis of all the assumptions and hypotheses underlying the model. Choosing incorrect models causes a bias of results and an increase in unexplained variability that worsens the analytical framework of an already very complex area issue.

This article attempts to address this lack of information by offering to researchers a useful tool with which to identify all the possible alternatives of models analysing the effects of climate change on agriculture. This article has reviewed the literature and discussed the most popular analytical methods that are presented in the literature, and that are: the Crop Simulation Models, the Production-Function Model, the Ricardian Model, the Mathematical Programming, the General Equilibrium Model (GEMs) and the Integrated Assessment Models (IAMs). It has classified methods of analysis according to the principal aspects that have to be considered in when selecting a model, with particular emphasis on the dimensions under which the effects of climate change should be expressed. The adopted classification scheme demonstrates that one model is capable of simultaneously considering many aspects related to climate change and classifying these in different classes.

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