Meta-analysis of climate impacts and uncertainty on crop yields in Europe

Detailed description on the systematic review (SR) methodology

This section provides detail on the methodology followed to develop this study, including the search strategy (terms, sources, and inclusion criteria), data analysis and synthesis (database and statistical analyses). It also includes a list of all the references used in this SR after screening.

We used a highly robust and rational systematic review methodology to synthesise the evidence from a wide range of sources. The approach followed the systematic review guidelines developed by the Centre for Evidence Based Conservation (CEBC) in conjunction with the Collaboration for Environmental Evidence (CEE).

In this study, we constrained the systematic review by defining boundaries to include: (i) Only bio-physical studies that took into account food crop production which was done within social economic context in specified locations in Europe; (ii) only studies which used projections of climate or the previous climate events, but not those related to underlying science of crop and animal response to one or more climatic factors; (iii) studies that focussed on crop productivity, omitting the forestry, fisheries, livestock and other non-food crop agricultural sectors; and (iv) studies that focused on food crop productivity and sustainable food systems from year to year.

The review did not consider ‘food production’ as this is dependent on non-biophysical factors, such as investment in irrigation, international trade policy and world market prices, nor did it consider the impact of climate related ‘shocks’ (flood, drought, pest attacks) on food productivity. Following SR convention, the research question was broken down into four components (PICO) (Table 1).

Table 1 Defining the PICO terms for the research ‘question’ used in this study.

PICO	Description
Population	Agriculture – specifically food crops, excluding grassland, fibre, commodity / industrial crops Crops included rice, wheat, maize, rye, barley, potatoes and sugar beet. Europe: Study included all the countries in the continent, not limiting their inclusion to the European Union
Intervention	Climate change as projected by various GCMs or ensembles Time-scale was from the current baseline through the 2020s, 2050s and up to 2080s Climate variables included were temperature (mean, seasonal variation) and rainfall (mean annual and seasonality). Changes in CO_2 concentration were included
Comparator	Baseline climate (usually 1961-90) but noted there were other ‘baselines’ in the literature which may constitute an ‘effect modifier’
Outcomes	Change in average yield and change in variability of yield; change in irrigation need; change in fertilizer / pesticide need; Change in crop suitability / sustainability; crop failure; drought

We recognise the difficulty in applying a SR in its classical form to climate impacts research, since the approach is more commonly used to synthesise results from experimental (e.g. medical) trials. By definition, it is impossible to evaluate the impacts of future climate on agriculture through experimentation. Scientific studies of the topic are inevitably based on models; both of climate and crop response. As the number of models available is limited there is a danger that the results of a meta-analysis are biased by assumptions implicit in the models. The search strategy therefore included defining the database sources, search websites and organisation websites (Table 2).

We initially trialled a set of contrasting English search terms in Web of Science during the protocol phase to test their effect on the number of literature 'hits'. Regional terms such as "Europe" and specific countries were not used as these would restrict the search and exclude studies that had a global perspective, but included Europe. The regional terms were screened later using the 'inclusion criteria'. The final search term was defined and used with *and ? denoting wildcards:

Climate change AND (Yield OR Fertili?er OR Irrigat* OR Product*)

This search term was then applied to the range of identified databases and search engines (Table 2). The literature was then retrieved (imported into Mendeley software) and screened for relevance using the following inclusion criteria:

Relevant subjects: Any countries/regions in Europe (as defined); any scale from field to region; any crops (as defined); include both small-scale and commercial agriculture.

Type of intervention: Climate change emission scenario for time slices 2020s, 2050s and 2080s; emission scenarios based on IPCC; projected changes in mean, total or seasonality.

Comparator: Future outcomes with present/baseline outcomes.

Method: Controlled experiments and/or biophysical modelling studies.

Outcomes: Studies that considered changes in crop suitability, yield, performance, variability and/or sustainability.

Table 2 Database sources and websites used for conducting the SR.

Database sources	Search websites	Organisation websites
ISI Web of Science (WoS); Scopus; EBSCO GreenFILE; CSA Natural Sciences; Directory of Open Access Journals; ScienceDirect; Ingenta Connect; InTute; FAO Corporate Document Repository	google.com; googlescholar.com; scirus.com	World Bank; FAO; Resources for the Future; World Bank; Consultative Group on International Agricultural Research (CGIAR); International Water Management Institute (IWMI); Climate Institute; Centre for Environmental Economics and Policy in Europe; European Environment Agency

The published date of literature included in the review was important as GCMs and emissions scenario are continually being updated. For this SR, literature preceding publication of the Third IPCC Assessment Report (2001) was excluded. The initial filtering was undertaken based on the 'Title' of the literature source; a second filter then based on the content in the 'Abstract'. The full text was only reviewed for literature once it had passed all inclusion criteria. This stage was undertaken by 2 researchers, working independently, to screen the literature. A cross comparison was then completed to ensure consistency between the researchers in the acceptance/rejection criteria being applied. The literature was therefore selected and screened in four discrete stages (i) Using the agreed keywords, search terms and databases we assembled a Mendeley literature database; (ii) Duplicates were removed, leaving 1748 unique sources that matched the search criteria. (iii) We screened the sources on 'Title' reducing the sample size to 566; (iv) We repeated the screening using Abstracts leaving 41 sources that met the inclusion criteria. A summary flow chart of the individual systematic review activities is given in the paper in Figure 1.

Data synthesis and statistical methods

The 41 sources contained yield projections for 729 observations with a mix of crop types, location, GCMs, crop models, and time slices. Each was expressed as a yield variation (± %) relative to a historical baseline yield to remove the effect of current regional yield variations. The yield variations extracted from each study could not be weighted, as would have been done in a conventional meta-analysis of experimental data from different sources, due to inconsistency in the methods of estimation and only partial reporting of the yield projections. As future yields were inevitably modelled using deterministic crop models, uncertainty in the projected yields reflects uncertainty in the climate change scenarios used to drive the models. Where ensemble approaches were used, variances were reported. However, many of the studies used either single climate change scenarios or perturbations of historical climate series and therefore no variance in the yield projections could be reported. To have excluded these studies would have substantially compromised the scope of the study; therefore unweighted standard parametric tests were used.

Mean yield projections were calculated for the entire dataset and sub-sets based on crop type, region, country, time-slice, and climate change methodology and each compared with a zero response by means of the Student t-test. Although sub-optimal, such methods give acceptable results in situations where sample sizes and variances are unavailable (Gurevitch and Hedges, 1999).

References

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European countries included in the systematic review

Northern Europe – Finland, Norway, Sweden, Denmark, Latvia, Estonia, Lithuania, UK, Ireland.

Central Europe – France, Germany, Belgium, The Netherlands, Luxemburg, Poland, Belarus, Ukraine, Czech Republic, Slovakia, Hungary, Moldova, Romania, Bulgaria, Austria, Switzerland.

Southern Europe – Portugal, Spain, Italy, Croatia, Greece, Malta, Cyprus, Macedonia, Serbia, Montenegro, Bosnia and Herzegovina, Albania.

List of references included in the SR meta-database

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