ERL Supplementary Information

Climate change impacts on crop productivity in Africa and South Asia

Detailed description of the systematic review (SR) methodology

This section provides detail on the methodology, including the search strategy (terms, sources, inclusion criteria), data analysis and synthesis (meta database and statistical analyses). A list of all the references used in the SR after screening is provided.

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). Prior to commencing the review, the protocol (which sets out the method, approaches and search criteria) was independently peer reviewed by DFID and CEE experts.

In this study, we constrained the systematic review by defining boundaries to include (i) only biophysical studies, recognising that agriculture is practiced within an economic and social context that is often location-specific; (ii) studies that only used climate projections (not those concerned with the underlying science of the response of crops and animals to one or more climate factors); and (iii) studies that focussed on crop productivity, omitting the forestry, fisheries, livestock and other non-food crop agricultural sectors.

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 – narrow down to food crops. Exclude grassland, fibre, commodity / industrial crops, fruit, and vegetables Crops included rice, wheat, maize, sorghum, millet, cassava, yams, plantain, and sugarcane. Most important accounting for 80% of total production in Africa and S Asia (FAO STAT) Africa and S Asia: Study included all African countries, rather than selected areas. Asia defined to include India, Pakistan, Bangladesh, Sri Lanka, Nepal, Bhutan and Afghanistan
Intervention	Climate change as projected by various GCMs Time-scale was from the current baseline (2010) up to the 2050s Climate variables included were temperature (mean, seasonal variation) and rainfall (mean annual and seasonality). Changes in $C0_2$ concentration 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 recognised 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).

Table 2 Database sources and websites for SR.

Database sources	Search websites	Organisation websites
ISI Web of Knowledge (WoK); Scopus;EBSCO GreenFILE; CSA Natural Sciences; Directory of Open Access Journals; ScienceDirect; Ingenta Connect; InTute; FAO Corporate Document Repository	google.com; googlescholar.com; dogpile.com; scirus.com	World Bank; FAO; Resources for the Future; World Bank; Consultative Group on International Agricultural Research (CGIAR); International Water Management Institute; Asian Development Bank; Climate Institute; Centre for Environmental Economics and Policy in Africa; Science and Development Network; International Fund for Agricultural Development (IFAD

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 "Africa" or "South Asia" and specific countries were not used as these would restrict the search and exclude studies that have a global perspective. The regional terms were screened later using the 'inclusion criteria' The final 2 search terms were defined and used with *and ? denoting wildcards:

1. Climate change AND (Rice OR wheat OR maize OR sorghum OR millet OR cassava OR yam* OR plantain* OR sugar*)
2. Climate change AND (Yield OR Fertili?er OR Irrigation OR Failure OR Disease OR Drought OR Soil OR Salinity)

These two search terms were then applied to the databases and search engines (Table 2), the literature retrieved (imported into Refworks software) and then screened for relevance using the following inclusion criteria:

Relevant subjects: Any countries/regions in Africa and S Asia (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 scenarios for time slices up to the 2050s; emission scenarios based on IPCC scenarios; projected changes in mean, total or seasonality.

Comparator: Future outcomes with present/baseline outcomes.

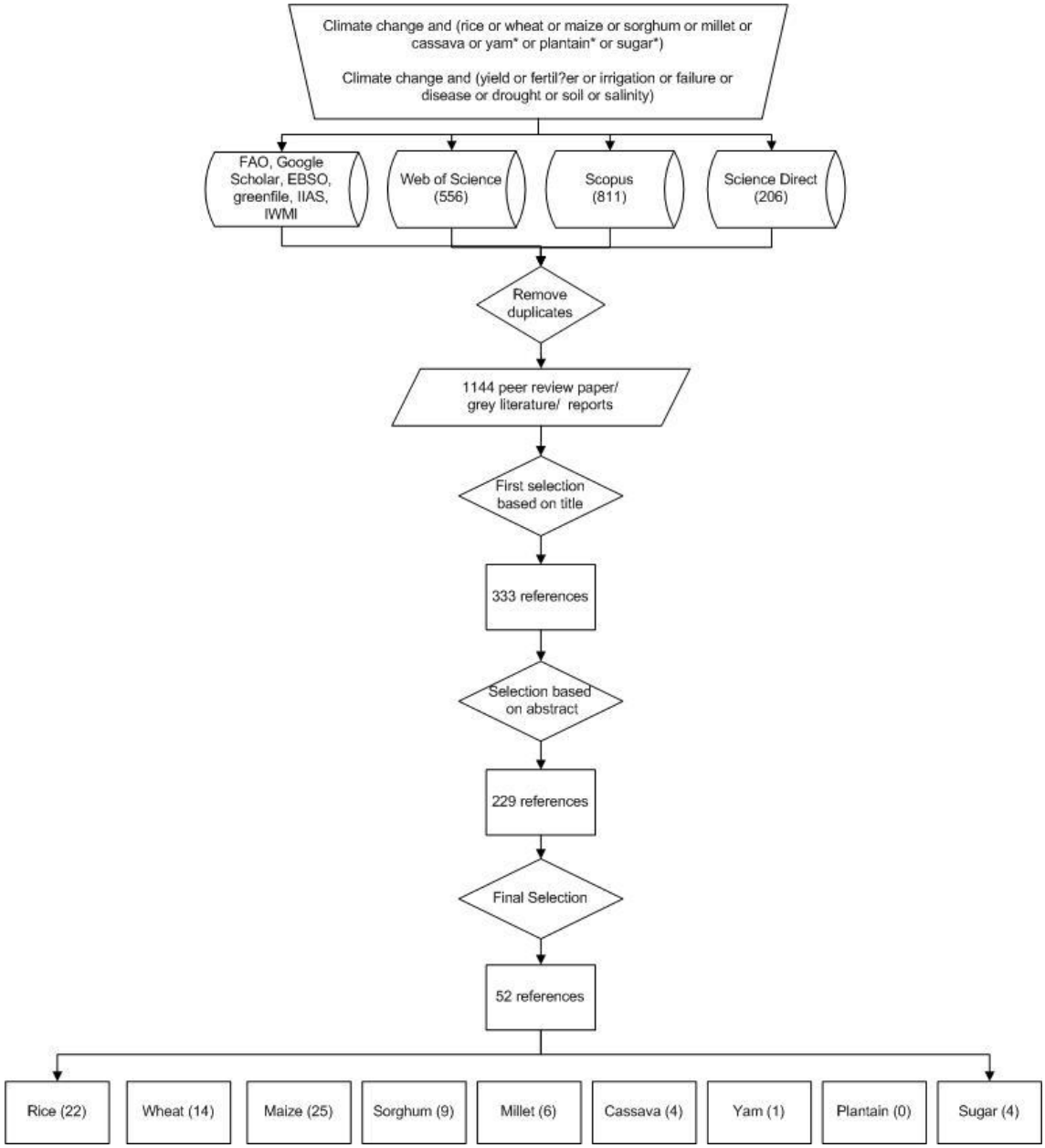
Method: Controlled experiments or biophysical modelling.

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

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 RefWorks literature database; (ii) Duplicates were removed, leaving 1144 unique sources that matched the search criteria. (iii) We

screened the sources on 'Title' reducing the sample size to 333; (iv) We repeated the screening using Abstracts leaving 52 sources that met the inclusion criteria. A summary flow chart of the individual systematic review activities is given in Figure 1.

Figure 1 Schematic overview of the individual stages in the systematic review.



Data synthesis and statistical methods

The 52 sources contained yield projections for 257 crops and locations. 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 variance 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 (e.g. Masutomi et al., 2009). 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 Student's t-test. Although sub-optimal, such methods give acceptable results in situations where sample sizes and variances an unavailable (Gurevitch and Hedges, 1999).

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Countries included in Africa and S. Asia in the systematic review

S Asia

South Asia – India, Pakistan, Nepal, Sri Lanka and Afghanistan

South East Asia – Bangladesh, Bhutan

Africa

Central Africa - Central African Rep, DR Congo, Congo, Equatorial Guinea, Gabon

East Africa – Burundi, Tanzania, Kenya, Uganda, Rwanda

North Africa – Algeria, Morocco, Egypt, Tunisia, Libya

Sahel - Burkina Faso, Mauritania, Chad, Niger, Eritrea, Senegal, Ethiopia, Somalia, Mali, Sudan

Southern Africa – Angola, Namibia, Botswana, South Africa, Lesotho, Swaziland, Madagascar, Zambia, Malawi, Zimbabwe, Mozambique

West Africa – Benin, Guinea-Bissau, Cameroon, Liberia, Côte d'Ivoire, Nigeria, Gambia, Sierra Leone, Ghana, Togo, Guinea

Listing of references included in the systematic review meta database

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ERL Supplementary Information

Maize yield and country analysis for Africa

Figure 2a Spatial distribution of maize production in Africa (expressed as % of total cropped area) derived from FAOStat (2012) in relation to the reported number of observations on the projected impacts of climate change on maize yield.

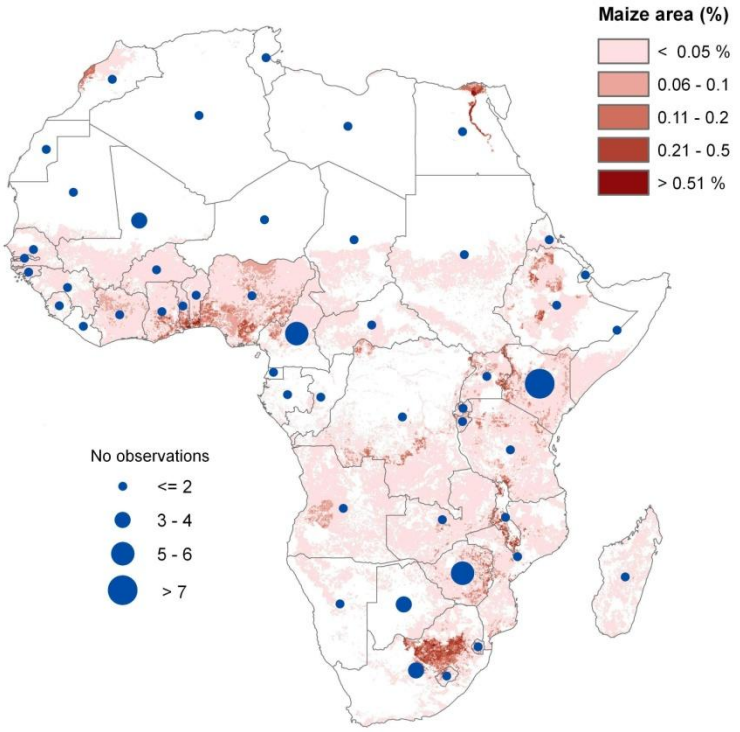

Figure 2b Proportion of maize cropped area (%) in relation to projected mean yield variation. The number of observations are also shown above each column. For example, Nigeria accounts for 11% of all maize grown in Africa, where the projected mean yield variation is estimated to be -18%, based on 1 observation.