ClimateCost

Project: ClimateCost

Project full title: Full Costs of Climate Change

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Work package 2B Agriculture and water

Deliverable 2B2: Report analysis for Europe

Participants

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Content

1 Introduction and objectives

1.1 Objectives of WP2B

This work package focuses on agriculture and water resources.

The general objective of WP 2B is to assess impacts from climate change on agriculture and water availability with and without adaptation. The physical impacts will be derived in detail from the scenarios of climate variability and change provided by WP1 for Europe. Possible impacts for China may be derived if climate scenarios and data for validation of the physical models are available. The results of the WP will generate the information for integrated assessment models and the economic models.

The methodology will be an extension of the PESETA-Agriculture methodology, incorporating water availability and management and land use. A literature review was presented in Deliverable 2B.1. This deliverable presents the analysis for Europe, including methodological aspects, model development and sensitivity tests to temperature and irrigation water availability.

The output from WP2B aims to understand policy questions related to vulnerability of regions and social groups, conflicts among water users and adequacy and revision of existing environmental policy in the context of climate change. The results will provide the quantitative estimation of agricultural production and water requirements to be used in the economic analysis; the water quantification of water availability for other sectors; evaluation of water requirements under climate and policy scenarios, the economic and environmental valuation of agricultural production and water.

Deliverables:

- 2B1 Report Review of literature. Month 6. (Completed)
- 2B2 Report Analysis for Europe (model ready). Month 15. (This deliverable)
- 2B3 Report Analysis of impacts and adaptation for all scenarios and regions. Quantification of water requirement satisfaction across all sectors and evaluation of policy implications and scenarios (application of the model). Month 24.

1.2 Objectives of deliverable D_2B2

This deliverable provides a methodology and model development for improved understanding of the potential implications of climate change and adaptation options for agriculture and water. It also aims to assist policy to address the proprieties for adaptation.

Following this section, this report includes a summary of the coordination with other WPs (section 2), the methodological approach (section 3), the description of the Peseta-A model and set of proposed policy simulations (section 4), and some preliminary results (section 5). Finally, the outline of the final analysis is presented in section 6.

2 Coordination with other WPs

2.1 Coordination of the land productivity estimates

Land productivity in the ClimateCost project is the result of interaction among several components of the project (WP 2F and WP 2B) and the demand for bioenergy (WP 4 and WP 2F). Figure 1 summarises the approach to integration of model components and estimation of uncertainty proposed by PIK, IIASA and UPM. WP2B will provide the final land productivity estimates to the coordinator of WP2. The estimates will be consistent with the bioenergy demand results produced by the POLES model. Evaluation of the uncertainty of these estimates will include: (1) uncertainty derived from the climate scenario; and (2) uncertainty derived from the model assumptions.

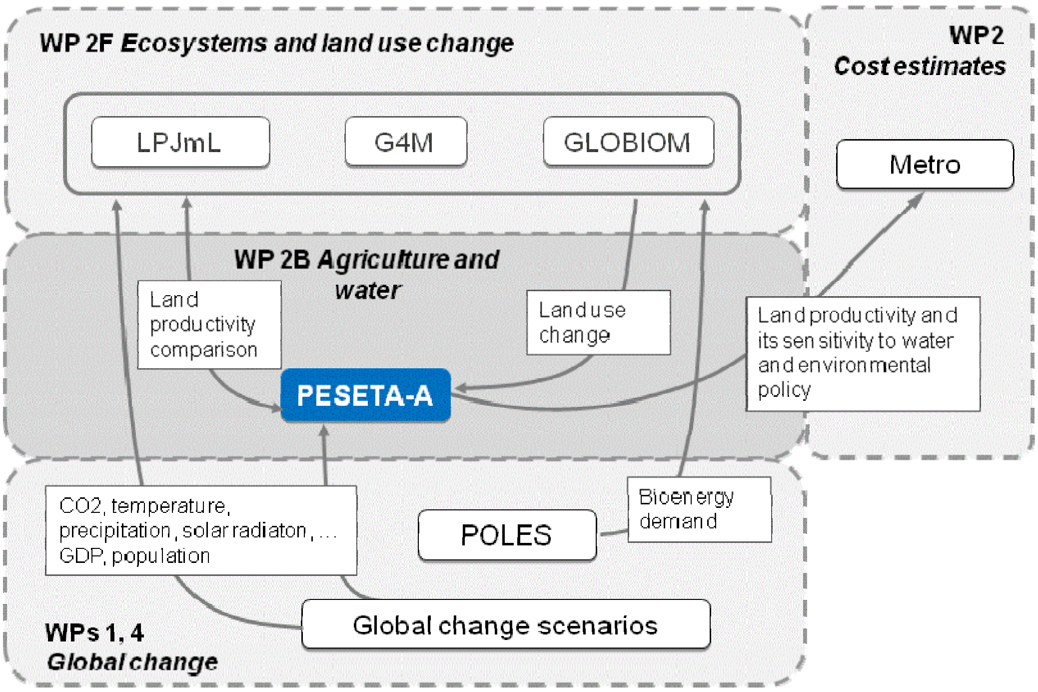

Figure 1 Integration of WP 2B with and linkages to other components of the ClimateCost project

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2.2 Input to the CG and integrated models

Three different information sets will be produced: the first to build the baseline(s) (without-climate-change-impacts) scenario (changes in productivity expected feom technological and land use changes), the second to quantify climate change impacts without adaptation, the third to determine climate change impacts with adaptation. Table 1 summarises the potential inputs to the CG models. The final information sets produced will be discussed with the leader of WP2.

Table 1 Data requirements and format

CG Model	Impacted economic variable		Data format
	Land quality (productivity)	Land quantity	
ICES	% change in 2 major crops productivity	% of land loss to desertification	Baseline construction, relevant data can be expressed in yearly % changes (for each year within the period 2001-2050) For the climate change scenarios, relevant data can be expressed in yearly basis in terms of % changes with respect to that year baseline value. Region specific data: USA, Europe 15, Europe 10, Korea-South Africa, Canada-Japan-Australia-New Zealand, Middle East-North Africa, Sub Saharan Africa, South Asia, China, East Asia, Latin and Central America.
GEM3	% change in 2 major crops productivity, bio-fuels 1 and 2 and biodiesel		To be decided
GCE			To be decided
IAM (PAGE 09)	% change in 2 major crops productivity		Baseline and scenario rages
FUND	To be decided		To be decided

3 Methodological approach

3.1 Land productivity

The framework is defined aiming to contribute to the **economics of adaptation** and the **energy policy effects** on land productivity and water requirements for agriculture. This is achieved by:

- defining consistent crop simulation methodology and climate change scenarios,
- establishing a consistent foundation for estimation of water supply and demand,
- considering different aspects of adaptation (social vulnerability and adaptive capacity),
- integrating land use and water impacts into the land productivity evaluation.

Table 2 summarises the key issues of the land productivity evaluation and the approach taken in this study.

Table 2 Methodological approach for the estimation of land productivity

Key issues	Approach in this study
Drivers of agricultural change considered	– Climate and socio-economic factors (global climate models and SRES scenarios)
Estimation of agricultural change	– Estimating crop production functions at the regional level that takes into account water supply and demand, social vulnerability and adaptive capacity. – Agricultural land use change – Land productivity derived from process based models that respond to climate, water availability, farm management and environmental policy – Irrigation water requirements corresponding to each climate and management option
Estimation of adaptation	– Integrated from the onset as part of the input definition of the system in the agricultural models
Current vulnerability to climate and extreme events	– Response to extreme events and underlying causes of impacts in current systems – Validation of the modelling tools under current conditions
Aggregation	– To be defined with leader of WP2

3.2 Water demand and supply

WATER DEMAND

Water demand for agriculture is estimated by defining irrigation requirements under the climate scenarios. This depends on land use, adaptation at the farm level and energy and environmental policy. Water demand is simulated directly with the agricultural models.

WATER SUPPLY

Water supply for rainfed agriculture depends on rainfall. But for irrigated agriculture depends on runoff and storage capacity. Water supply will be estimated by estimating an index of changes in runoff and system reliability based on existing data.

Hydraulic infrastructure plays a critical role to make water available to users by overcoming the spatial and temporal irregularities of the natural regimes.

System modellers estimate demand reliability, quantified as the probability that a given demand may suffer water shortages during a given time horizon. This reliability index is normally used for decision making, identifying demands that do not comply with a pre-specified minimum standard, in order to evaluate the effect of water conservation or yield enhancement actions for these demands, and defining the measures to correct the reliability deficit.

Three factors are at play in regulated water resource systems: streamflow variability, storage capacity and yield reliability. These are usually linked through storage-yield-performance characteristics, which describe how a system is able to supply its demands and with what reliability. There is a wide range of techniques which can be applied for this purpose, from relatively simple regression functions relating these variables to highly complex water resource systems models. Usually, these complex simulation or optimization models are used by water resources engineers in areas prone to water scarcity. The result of the analysis is an estimation of the reliability of supply for each demand present in the system.

The availability of reservoir storage for regulation of natural resources is an indicator of robustness to climate changes, especially in the case of within-year regulation systems. If streamflow variability remained constant, the percentage reduction of available water resources in systems with adequate reservoir storage volume would be less than the percentage reduction of natural river discharge. Systems with small regulation capacity, or systems with an excess of it, show a poorer response to reduced streamflow. In the first case, the lack of reaction is due to the lack of flexibility of the regulation system, and a given percentage reduction of river discharge results in an almost equal reduction of available water resources. In the second case, the lack of reaction is due to the exhaustion of the regulation capacity of the basin, where almost a 100% of natural resources are made available.

Water resources simulation models may be too complex for this type of analysis, because they require very detailed information of naturalised streamflow series in each scenario, and they include a representation of system demands which may change over time as a result of adaptation measures. In the context of Climate Cost, it is beyond the objectives of the project to collect detailed data on selected basins in the area of study and perform simulations under climate change scenarios to obtain restrictions on the social system imposed to water availability.

A possible alternative is the application of generalized storage–yield performance relationships, like the Gould-Gamma model (McMahon, 1993). These relationships provide a method to analyze the storage–yield problem using simple input factors such as the coefficient of variation of streamflow and the required system reliability. Adeloye et al., 2003 use the methodology to derive storage–yield curves for no failure (100% reliability) in several locations in the world. If an estimation of the climatic change of annual flow and coefficient of variation is available for these locations (inferred from results of GCMs), the methodology would allow for the estimation of water availability under different reliability requirements. This would be a relevant input to proceed with the analysis of future socioeconomic scenarios.

3.3 Adaptation

CURRENT ADAPTIVE CAPACITY

The development of adaptation scenarios should include stakeholder participation since the stakeholders are both the demand-drivers and the end-users of vulnerability analysis. Stakeholders include a wide range of people ranging from local and national policy-makers to individual land managers, such as farmers. The essential first step for evaluating future adaptation is to characterize current adaptive capacity in order to determine the challenges and opportunities for future management. Table 3 summarizes the categories and indicators of adaptive capacity attributes.

Table 3 Categories and indicators of adaptive capacity

Coping capacity category	**Indicators**
Environmental	– Resource base : Water supply; soil quality and diversity; land size and distribution; land unmanaged; population density – Risk: Variability of the current climate and extreme events
Economic	– Resource base: Land tenure and size; financial capital; material equipment and machinery; animals; GDP per capita – Risk: Variability in production; variability in input and output prices – Financial resources: Access to formal and informal credit – Diversity: Diversity of the agricultural system (seeds available and used and number of crops planted); diversity of income sources (agriculture, livestock, off-farm and non-farm) – Variability in the rural economy: Migration; land sales, land rental – Agricultural innovation and information dissemination: Public expenditure in agricultural research and extension / population; technological gap for cereal production
Social	– Resource base: Population in the workforce; education; age; gender – Support programs: Technology transfer; technical assistance – Social programs: Emergency welfare programs; social services – Economic capacity: GDP per capita. – Human and civic resources: % population in the workforce; % population with literacy level. – Agricultural innovation and information dissemination: Public expenditure in agricultural research and extension/population; Technological gap for cereal production. – Renewable natural capital: Population density; % land unmanaged.

THE CHOICES FOR AGRICULTURAL ADAPTATION

While most adaptation to climate change will ultimately be characterised by responses at the farm level, encouragement of response by policy affects the speed and extent of adoption. Most major adaptations may require 10 to 20 years to implement. Two broad types of adaptation are considered here: farm-based adaptation and policy adaptation. Farm based adaptation includes changes in crops or crop management. All measures may contribute to adapt to climate change but in many cases may have other negative effects, such as environmental damage. Policy based adaptation creates synergies with the farmers' responses particularly in countries where education of the rural population is limited. Agricultural research to test the robustness of alternative farming strategies and development of new crop varieties are also among the policy based measures with a potential for being effective in the future.

A major factor that may contribute to mitigate or intensify impacts of climate change on water resources in semiarid regions is management of the water resources system. Adequate rules for management of irrigation systems under drought conditions can significantly offset the reduction in natural inputs. The measures of demand management can also achieve a progressive reduction of the needs far greater than the reduction of available water supply which occurs naturally as a result of climate change. This requires a coordinated series of actions in terms of awareness and education, investment in conservation, maintenance and improvement of facilities, establishment of rules for exchanging water rights and increasing the flexibility of the operation of the water resource system.

4 Peseta-A model

4.1 Components

The basic tool is the Peseta-A model system. PESETA-A addresses climate change impacts and adaptation in agriculture and water resources for agriculture. The model integrates land and water spatial analysis, agricultural models, policy analysis, and economic valuation. A preliminary version of some model components was developed in the Peseta project (http://peseta.jrc.ec.europa.eu/). Here the PESETA-A is further developed to include land use and water interactions and policy analysis. Figure 2 summarises the model components.

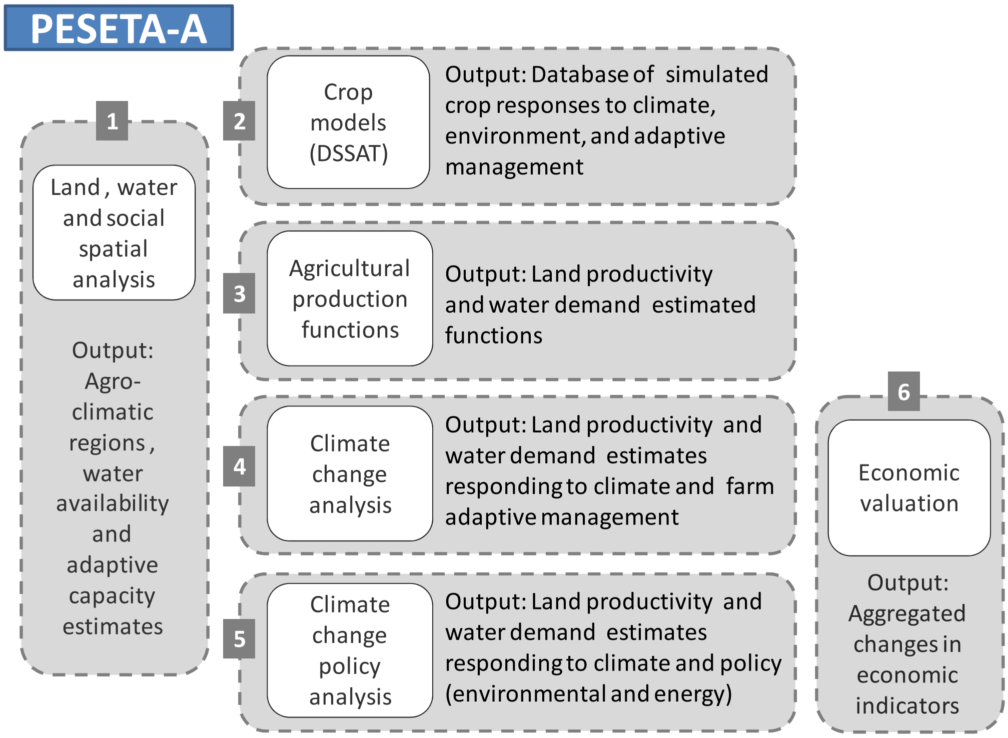

Figure 2 PESETA-A model components

4.2 Climate change and policy analysis

Figure 3 outlines the component of climate change and policy analysis. The model is defined to analyses four levels of adaptation:

Level 1: optimisation of land productivity by actions taken at the farm level (no policy intervention)

Level 2: management with policy that emphasises water resources protection and urban development

Level 3: management with policy that emphasises protection of agricultural production and rural development

Level 4: increase in biofuels of more than 20%

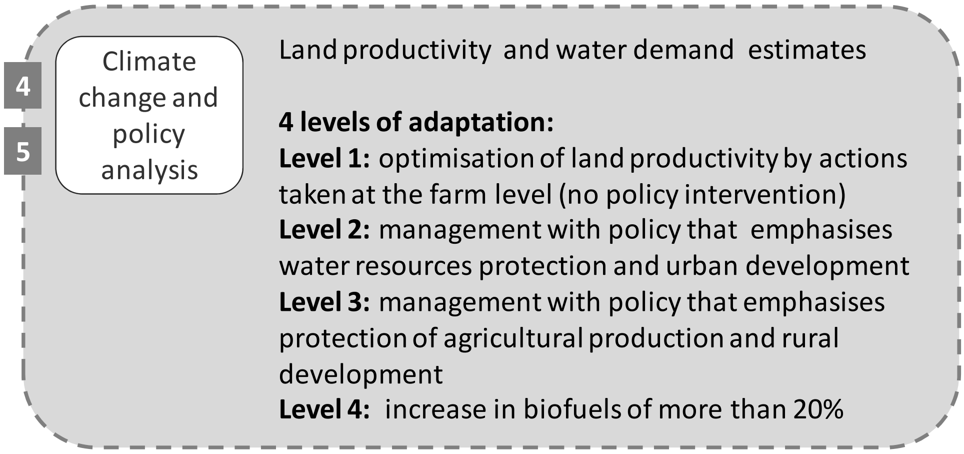

Figure 3 Climate change and policy analysis in the PESETA-A model

5 Preliminary results

Table 4 summarises the Preliminary results of the simulation of land productivity in the European regions under 3 temperature and adaptation scenarios. Further simulations will be performed when the climate change scenarios are available and the adaptation and mitigation options are discussed with the coordinator of WP2. THe final simulations will be presented in maps.

Table 4 Preliminary results of the simulation of land productivity in the European regions under 3 temperature and adaptation scenarios

	Land productivity changes (average of all crops)					
	Scenario +2C Adaptation with water restrictions		Scenario +2C Adaptation with water unlimited		Scenario +4C Adaptation with water restrictions	
European Region	**avg_%**	**SD_%**	**avg_%**	**SD_%**	**avg_%**	**SD_%**
Boreal	30	23	5	27	42	24
Continental North	1	3	2	5	3	2
Continental South	6	5	4	22	7	11
Atlantic North	0	0	0	11	0	0
Atlantic Central	-1	6	6	26	4	1
Atlantic South	0	0	0	30	0	0
Alpine	8	7	13	8	16	15
Mediterranean North	-9	1	2	2	-19	-18
Mediterranean South	-2	10	11	9	- 22	-4

6 Outline of the final analysis

The final analysis will be conducted when climate change scenarios are produced and adaptation options are clearly defined in coordination with the rest of the WPs.

Figure 3 shows the geographical extend of the analysis and Table 5 the output produced with the European focus.

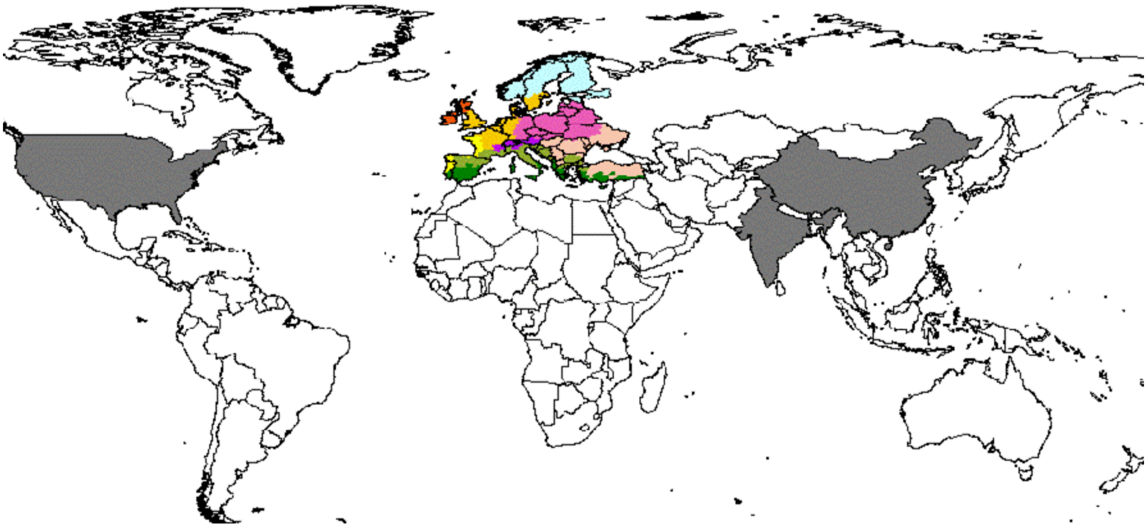

Figure 3 Extent of the analysis

Table 5 Output of WP2B for Europe

European focus	Output of WP2B
Climate and social signals	Climate alone: scenarios Social alone: technological change; water management
Time frames	Current?, 2030, 2050, 2080
Impacts and valuation metrics	Land productivity
Crops	3 groups of crops (all crops, irrigated crops, grain rainfed crops), 4 adaption scenarios, EU, China, India, USA
Uncertainty	scenarios, productivity estimates with different models, monte carlo
Adaptation	– adaption scenarios – adaptive capacity – linkage to EU policy – Private and policy changes of water and land management (hard and soft)
Mitigation (links to WP4)	– Nitrogen-limited adaptation scenarios
Ancillary benefits (links to WP5)	– Water adaptation scenarios (consequences for urban supply and ecosystems services)

7 References

Antle JM, Capalbo SM (2001) Econometric-Process Models for Integrated Assessment of Agricultural Production Systems. American Journal of Agricultural Economics 83(2):389-401

Arnell NW (2004) Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change, 14(1), 31-52

Barnett TP, Adam JC, Lettenmaier DP (2005) Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438, 303-309

Brooks N, Adger WN, Kelly PM (2005) The determinants of vulnerability and adaptive capacity at the national level and implications for adaptation. Global Environmental Change, 15, 151-163

Burke EJ, Brown SJ, Christidis N (2006) Modelling the recent evolution of global drought and projections for the 21st century with the Hadley Centre climate model. Journal of Hydrometeorology, 7(5), 1113-1125

Burton I, Lim B (2005) Achieving adequate adaptation in agriculture. Climatic Change, 70(1- 2), 191-200

COM(2007/354) Adapting to climate change in Europe – options for EU action. Brussels, 29 June 2007

Darwin R (2004) Effects of greenhouse gas emissions on world agriculture, food consumption, and economic welfare. Climatic Change 66, 191–238

Dimaranan BV, McDougall RA (2006) Guide to the GTAP Data Base. Global Trade, Assistance, and Production: The GTAP6 Data Base. Dimaranan [ed], Center for Global Trade Analysis. Purdue University

Döll P (2002) Impact of Climate Change and variability on Irrigation Requirements: A Global Perspective. Climate Change, 54, 269–293

Downing TE, Patwardhan A (2005) Assessing Vulnerability for Climate Adaptation. Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures, B. Lim, E. Spanger- Siegfried, I. Burton, E. Malone, and S. Huq, Eds., Cambridge University Press, Cambridge and New York, 67–90

Eckhardt K, Ulbrich U (2003) Potential impacts of climate change on groundwater recharge and streamflow in a central European low mountain range. Journal of Hydrology, 284, 244–252.

EEA (2008) Impacts of climate change in Europe: An indicator based report.

Evenson RE (1999) Global and local implications of biotechnology and climate change for future food supplies. Proc. Nat. Acad. Sci., 96, 5921-5928

Ewert F, Rounsevell MDA, Reginster I, Metzger MJ, Leemans R (2005) Future scenarios of European agricultural land use I. Estimating changes in crop productivity. Agriculture, Ecosystems and Environment, 107, 101-116

Fankhauser S, Tol RSJ (2005) On Climate Change and Economic Growth. Resource and Energy Economics, 27, 1-17

Garrote L (1995) Flood vulnerability assessment and management. Natural Risk and Civil Protection (Horlick-Jones, Amendola, Casale, eds.) – ISBN 0-419-19970-5. Pp: 213 -- 225. Chapman Hall: London

Garrote L (1996) RIBS: Distributed rainfall-runoff modelling for the Arno basin Integrating Radar Estimates of Rainfall in Real Time Flood Forecasting (Borga, Casale, eds.) ISBN 88-7740-209-X. Pp: 143 -- 152. 1996. Bios. Padova (Italy)

Garrote L, Bras RL (1995) An integrated software environment for real-time use of a distributed hydrologic model. Journal of Hydrology – ISSN – 0022-1694 167 Pp: 307 -- 326. 1995. Elsevier. Amsterdam

Garrote L, Molina M (2004) A framework for making probabilistic forecasts using deterministic rainfall-runoff models. Hydrological risk (Brath, Montanari, Toth, eds.) ISBN 88-7740-378-0. Pp: 239 -- 246. 2004. Bios. Italy

Giorgi F, Lionello P (2008) Climate change projections for the Mediterranean region. Global and Planetary Change, 63 , pp. 90–104

Gleick PH (2003) Global Freshwater Resources: Soft-Path Solutions for the 21st Century. Science Vol. 302, 28 November, pp. 1524-1528

Hansen JW, Jones JW (2000) Scaling-up crop models for climate variability applications. Agricultural Systems, 65, 43–72

Hulme M, Barrow EM, Arnell NW, Harrison PA, Johns TC, Downing TE (1999) Relative impacts of human-induced climate change and natural climate variability Nature 397, 688-691

Iglesias A (2003) Water availability for agriculture under climate change: understanding adaptation strategies in the Mediterranean. Pages 75-93 in Climate change in the Mediterranean, socio-economic perspectives of impacts, vulnerability and adaptation. Giupponi, C. and M. Shechter (eds). Edward Elgar, United Kingdom

Iglesias A, Avis K, Benzie M, Fisher P, Harley M, Hodgson N, Horrocks L, Moneo M, Webb J (2007) Adaptation to Climate Change in the Agricultural Sector. AGRI-2006-G4-05. Report to European Commission Directorate -General for Agriculture and Rural Development. ED05334. Issue Number 1. December 2007. AGRI/2006-G4-05

Iglesias A, Cancelliere A, Cubillo F, Garrote L, Wilhite DA (2008) Coping with drought risk in agriculture and water supply systems: Drought management and policy development in the Mediterranean. Springer, The Netherlands

Iglesias A, Garrote L, Flores F, Moneo M (2007) Challenges to mange the risk of water scarcity and climate change in the Mediterranean. Water Resources Management, 21(5), 227-288

Iglesias A, Garrote L, Quiroga S, Moneo M (2010b) A regional comparison of the effects of climate change on agriculture in the European Union. Submitted to Climatic Change

Iglesias A, Minguez MI (1997) Modelling crop-climate interactions in Spain: Vulnerability and adaptation of different agricultural systems to climate change. Mitigation and Adaptation Strategies for Global Change, 1 (3), 273-288

Iglesias A, Moneo M, Quiroga S, Garrote L (2010a) Re-thinking the impacts of climate change on agriculture in the European Union. Submitted to Climatic Change

Iglesias A, Quiroga S (2007) Measuring cereal production risk form climate variability agross geographical areas in Spain. Climate Research 34, 47-57.

Iglesias A, Rosenzweig C, Pereira D (2000) Agricultural impacts of climate in Spain: developing tools for a spatial analysis. Global Environmental Change, 10, 69-80.

Iglesias A, Ward MN, Menendez M, Rosenzweig C (2003) Water Availability for Agriculture Under Climate Change: Understanding Adaptation Strategies in the Mediterranean. In: M. Shechter and Giupponi, C. (eds.). Climate Change and the Mediterranean: Socioeconomic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar Publishers, Northampton

IPCC (2007) Climate Change 2007: Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Long S, Ainsworth EA, Leakey ADB, Nösberger J, Ort DR (2006) Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO2 Concentrations. Science 312: 1918-1921

Martín-Carrasco F, Garrote L, Granados A (2003) Selecting hydraulic projects under uncertainty. Transactions-International Commission on Large Dams –ISSN 0254-0703. 21 Pp: 657 -- 667. ICOLD. Montligeon (France)

Medri S, Castellari S, Konig M (Eds.) (2007) Report on the current state of National Research Programmes on Climate Change Impacts and Adaptation in Europe, CIRCLE (Climate Impact Research for a Larger Europe)

Mimikou MA, Baltas E, Varanou E, Pantazis K (2000) Regional impacts of climate change on water resources quantity and quality indicators. Journal of Hydrology, 234, 95–109

Nijssen B, O'Donnell GM, Hamlet AF, Lettenmaier DP (2001) Hydrologic Sensitivity of Global Rivers to Climate Change, Climatic Change, Vol 50(1-2), 143-175

Olesen J, Bindi M (2002) Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy 16, 239-262.

Parry ML, Rosenzweig C, Iglesias A, Fischer G (2001) Millions at Risk: Defining Critical Climate Change Threats and Targets. Global Environmental Change, 11:181-183

Parry ML, Rosenzweig C, Iglesias A, Livermore M, Fischer G (2004) Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Environmental Change 14 (2004) 53–67

Patt AG (1999) Extreme outcomes: the strategic treatment of low probability events in scientific assessments. Risk Decision and Policy 4, 1–15

PICCMAT (2008) Policy Incentives for Climate Change Mitigation Agricultural Techniques. European Commission, DG Agriculture, Specific Support Action. Brussels, October 2008

Porter JR, Semenov MA (2005) Crop responses to climatic variation. Philosophical Transactions of the Royal Society B: Biological Sciences, 360, 2021-2035

PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects) http://prudence.dmi.dk/

Quiroga S, Iglesias A (2007) Projections of economic impacts o climate change in agriculture in Europe. Economia Agraria y Recursos Naturales 7(14): 65-82. (in English)

Rosenzweig C, Iglesias A (2003) Potential Impacts of Climate Change on World Food Supply: Data Sets from a Major Crop Modelling Study. http://sedac.ciesin.columbia.edu/giss_crop_study/

Rosenzweig C, Iglesias A, Fischer G, Liu Y, Baethgen W, Jones JW (1999) Wheat yield functions for analysis of landuse change in China. Environmental Modelling and Assessment 4:128-132

Rosenzweig C, Iglesias A, Yang XB, Chivian E, Epstein P (2001) Climate Change and Extreme Weather Events: Implications for Food Production, Plant Diseases, and Pests. Global Change and Human Health. 2, 90-104

Rosenzweig C, Parry ML (1994) Potential impact of climate change on world food supply. Nature 367, 133-138

Rosenzweig C, Strzepek K, Major D, Iglesias A, Yates D, Holt A, Hillel D (2004) Water availability for agriculture under climate change: Five international studies Global Environmental Change, 14, 345–360

Rounsevell MDA, Reginster I, Araujo MB, Carter TR, Dendoncker N, Ewert F, House JI, Kankaanpaa S, Leemas R, Metzger MJ, Schmit P, Tuck G (2006) A coherent set of future land use change scenarios for Europe. Agriculture Ecosystems and Environment 114, 57-68.

Schär C Vidale PL, Lüthl D, Frei C, Häberli C, Liniger MA, Appenzeller C (2004) The role of increasing temperature variability in European summer heatwaves. Nature, 427, 332–336

Semenov MA, Wolf J, Evans LG, Eckersten H, Iglesias A (1996) Comparison of wheat simulation models under climate change. II. Application of climate change scenarios. Climate Research 7, 271-281

Smith P, Daniel Martino, Zucong Cai, Daniel Gwary, Henry Janzen, Pushpam Kumar, Bruce McCarl, Stephen Ogle, Frank O'Mara, Charles Rice, Bob Scholes, Oleg Sirotenko, Mark Howden, Tim McAllister, Genxing Pan, Vladimir Romanenkov, Uwe Schneider and, Sirintornthep Towprayoon (2007). Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture Ecosystems and Environment, 118, 6-28

Smith P, Z. Somogyi, E. Trines, M. Ward and Y. Yamagata (2007) Greenhouse gas mitigation in agriculture. Philosophical Transactions of Royal Society, 363(1492), 789-813

Stern N, Peters S, Bakhshi V, Bowen A, Cameron C, Catovsky S, Crane D, Cruickshank S, Dietz S, Edmonson N, Garbett SL, Hamid L, Hoffman G, Ingram D, Jones B, Patmore N, Radcliffe H, Sathiyarajah R, Stock M, Taylor C, Vernon T, Wanjie H, Zenghelis D (2006) Stern Review: The Economics of Climate Change, HM Treasury, London

Tubiello FN, Ewert F (2002) Simulating the effects of elevated CO2 on crops: approaches and applications for climate change. European Journal of Agronomy 18, 1-2, 57-74

Vorosmarty C, Green P, Salisbury J, Lammers RB (2000) Global water resources: Vulnerability from climate change and population growth. Science, 289, 284-288

Wesley E, Peterson F (2005) Agricultural Structure and Economic adjustment. Agriculture and Human Values, 3(4), 6-15

Wullschleger SD, Tschaplinski TJ, Norby RJ (2002) Plant water relations at elevated CO2 - Implications for water-limited environments. Plant Cell Environ., 25(2), 319-331