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Review

# Adaptation strategies for agricultural water management under climate change in Europe

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ABSTRACT

Climate change is expected to intensify the existing risks, particularly in regions where water scarcity is already a concern, as well as create new opportunities in some areas. Efforts to develop adaptation strategies for agricultural water management can benefit from understanding the risks and adaptation strategies proposed to date. This understanding may assist in developing priorities for the adaptation of water resources for irrigation. Here we characterise the main risks across European regions and evaluate adaptation strategies by reviewing over 168 highly relevant publications that appeared in the last 15 years. Based on this extensive database we characterise the effort and benefit of a number of agronomic and policy measures, aiming to develop concrete adaptation plans and responding to concrete regional challenges. The adaptation choices consider current technological perspectives and do not project future technological change; we are certain that technological change will shape some choices for adaptation in the coming decades. The greatest scope for action is in improving adaptive capacity and responding to changes in water demands, however the implementation requires revamping current water policy, adequate training to farmers and viable financial instruments. These results aim to assist stakeholders as they take up the adaptation challenge and develop measures to reduce the vulnerability of the sector to climate change.



**Contents**



## 1. Introduction

Water management for agriculture is becoming increasingly complex. The challenges of climate change will have to be met through adaptation. Agriculture is an important sector in Europe

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providing employment opportunities to rural population, and supporting food security goals. However, agriculture requires water, an increasingly scarce resource. Choices for agricultural water management include a large range of technical, infrastructure, economic and social factors. Irrigated agriculture is protected to some extent from natural variability by hydraulic infrastructure, but the sector uses a major share of the available water resources in the world. Agriculture water needs must be supplied in a context of diminishing availability, due to environmental awareness, population growth, economic development and global change. As a consequence, water management for agriculture is inter-related not only to traditional water resources management, but also to food production, rural development and natural resources management.

Climate change will add to the many economic and social challenges already being faced by water management in agricultural areas (Rosenzweig et al., 2004; EEA, 2012a,b,c; Iglesias et al., 2011a; IPCC, 2008). While some aspects of climate change such as increased precipitation may bring some localised benefits, there will also be a range of adverse impacts, including reduced water availability and more frequent extreme weather (Alcamo et al., 2007; Arnell and Delaney, 2006; Arnell et al., 2011; Easterling et al., 2000; Rosenzweig et al., 2004; Iglesias et al., 2007). These negative impacts may put current water management, especially at the level of individual land managers and regions, at significant risk (summary of evidence in IPCC, 2014).

To advance the understanding of adaptation choices for agricultural water management, this study reviews 168 recent publications related to the multiple dimensions of adaptation of water management for agriculture: from technical aspects to barriers and motivations to public support. This study then links climate change impacts to the development of adaptation strategies for European regions. It aims to facilitate an improved understanding of the potential implications of climate change and adaptation options for agricultural water management and thereby assist policy makers as they take up the adaptation challenge and develop measures to reduce the vulnerability of the agricultural sector to climate change.

With the aim of providing support for adaptation planning, we believe two questions are particularly relevant: what are the adaptation needs in view of climate change? How successful are the proposed adaptation strategies in overcoming the risk posed by climate change? We address these questions by evaluating the risks of climate change for water for agriculture and then linking these risks to the development of adaptation strategies for agricultural water management.

The paper is structured into 5 sections: Section 1 is the introduction; Section 2 presents the methods and data; Section 3 presents regional risks and opportunities for water availability for irrigation in European agricultural areas; Section 4 presents an analysis of the adaptation choices to increase the sustainability of water resources allocation for irrigation in view of the impacts of climate change; and Section 5 discusses the results and draws a conclusion.

## 2. Data and methods

### 2.1. Framework and data

The framework of the study consists of a series of steps representing a logical progression from an assessment of climate change risks and opportunities, identification of adaptation options and evaluation of the most adequate ones for implementation, aiming to inform adaptation priorities and policies (Fig. 1). The assessment is a review of the available literature covering climate change projections, impacts on water needs for agriculture and water availability, and potential responses to overcome the negative impacts,

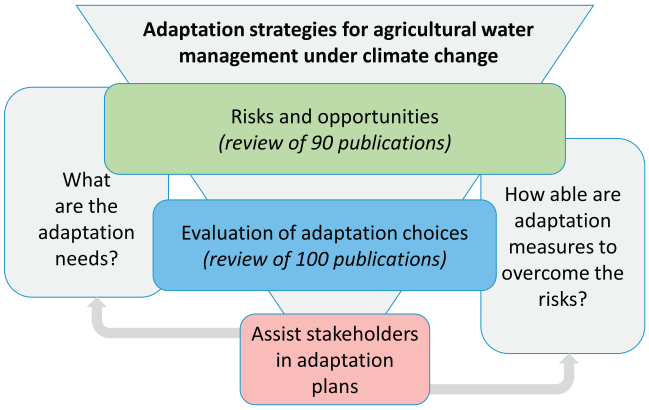


**Fig. 1.** Structure of the study and research questions. The total number of publications is 168, some publications overlap in the two components, and some are included only to support our discussion.

all of which are relevant to understanding the use of water for agriculture in the 21st century. The study includes 168 highly relevant publications from 1999 to 2014, cited in peer reviewed journals, and reports of the World Bank, United Nations, European Commission, European Environment Agency and OECD. Some publications overlap in the two components and some are included only to support our discussion.

### 2.2. Defining the risks and opportunities

Risks and opportunities were identified in relation to projected impacts to water availability and water needs for agriculture. We identified those that need to be addressed most urgently and provided a rationale for focusing the adaptation assessment on key issues. The likelihood of risks and opportunities was assessed using estimates of certainty of impacts provided in the literature. These vary in their comprehensiveness. In some circumstances, we have an estimate of certainty for the impact of climate change on farming activities; in other cases, we only have an uncertainty score for the general effects of climate change on a sector. We have used published information where possible.

### 2.3. Selecting adaptation choices and criteria for evaluation

The selection of adaptation measures and their attributes is based on a subset of the 168 publications, that is 100 studies that include information on specific adaptation measures (see Section 2.1). Here we propose an evaluation based on the most common listed attributes in the literature, particularly on two studies: first, De Bruin et al. (2009) described an inventory of climate adaptation options and provided a ranking of the different alternatives in The Netherlands, including options for water for agriculture. Their study evaluates the options based on stakeholder analysis and expert judgement, and presents some estimates of incremental costs and benefits. Second, the qualitative assessment focuses on ranking and prioritisation of adaptation options. Mukheibir defined criteria used for strategy analysis with experts, such as technical difficulty, potential costs of implementation and potential benefit. These criteria are widely used in adaptation studies (Leary, 1999; Burton and Lim, 2005), although each study quantifies these indicators in different ways. Here we have a qualitative approach based on published studies and synthesised by Iglesias et al. (2006). As result we have selected the attributes to evaluate adaptation strategies presented in the results section.

Table 1 outlines the criteria for the evaluation of the choice of adaptation measures in this study. The type of measure largely determines the extent to which water managers or farmers can