

METHODS TO ASSESS COSTS OF DROUGHT DAMAGES AND POLICIES FOR DROUGHT MITIGATION AND ADAPTATION: REVIEW AND RECOMMENDATIONS

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ABSTRACT

This article examines available methods for assessing all types of drought costs, including both damage costs and costs arising from adopting policy measures to encourage mitigation of, and adaptation to, droughts. It first discusses damage costs, distinguishing between direct, indirect and intangible costs. We examine the suitability of existing methods for estimating drought costs in different economic sectors, their underlying theoretical assumptions, complementarity between different methods, and conditions relevant for applications. The latter include precision, ability to deal with future climate change risks, data needs and availability, and required financial and human resources. The article further assesses potential policies for drought mitigation and adaptation as well as available methods for estimating their costs. It ends with providing recommendations for good practices with respect to methods and drought mitigation and adaptation policies.

1 INTRODUCTION

Drought is a natural hazard which causes many economic, social and environmental problems in different parts of the world. It is expected that the intensity and frequency of droughts are going to increase in the future due to climate change. This will certainly raise the importance of estimating drought damages. In Europe, a warmer and dryer climate is expected in many countries, particularly in the Mediterranean region.

Compared to other natural hazards, such as floods or storms, droughts are harder to identify and more complex to measure because they entail particular, unique features. First of all, drought is a relative concept because it depends on deviations from a historical record for a specific area. This means that droughts are not uniformly defined over space and time. Moreover, a drought generally develops at a much slower pace and lasts longer than other natural hazards (while its duration can vary considerably), making it difficult to identify an onset or an end of a drought. One should further realize that droughts usually cause fewer visible infrastructural damages (except for damages from ground subsidence and fires). Their impacts are more indirect and diffuse (scattered in space and across activities) in comparison with other natural hazards.

The existing literature on the costs of drought is scarce, fragmented and heterogeneous. Cost assessments of drought damages and drought mitigation and adaptation policies provide crucial information for decision support and policy development in the fields of natural hazard management and planning for adaptation to climate change. For these reasons, it is becoming increasingly important to identify and evaluate different approaches for estimating the costs of droughts, including both drought damages and drought mitigation and adaptation policies.

The remainder of article is organized as follows. Section 2 analyzes the existing methods for drought cost assessment. Section 3 discusses drought mitigation and adaptation policies and the most appropriate methods for their assessment. Finally, Section 4 provides recommendations and concludes.

2 OVERVIEW OF METHODS FOR DROUGHT COST ASSESSMENT

Traditionally, more emphasis has been placed on identifying and estimating the economic than environmental or social impacts of droughts. This particularly holds true for agricultural sector, which is usually the the most affected sector by droughts. The impacts of drought in a resource-based sector like agriculture are direct and consequently better understood and quantified more easily than (indirect) impacts on other, non-resource-based sectors of the economy. Impacts on resource-based sectors like water supply and hydropower have received less attention. The effects of droughts on other sectors, such as tourism, transport and energy, have begun to gain more attention in the literature. Social and environmental drought impacts are still not very well understood and are difficult to quantify. Nevertheless, there is nowadays more awareness of their importance and inclusion as part of total drought costs. This section provides an overview of methods for assessing different types of drought costs – direct, indirect and intangible costs.

Direct costs of droughts refer to losses in resource-based sectors like agriculture (e.g. reduced crop and livestock production), losses related to reduced water availability (e.g. water-providing companies, hydroelectric production, water transport), and damages on buildings and infrastructure due to ground subsidence. The last category has received particularly little attention in the literature. A reason may be the lack of data on damage from subsidence. Indeed, the two studies that exist (Dlugolecki, 2007; Corti et al., 2009) have been conducted for the countries where insurance against subsidence exists, which does not seem to be the case in most of the countries. Indirect costs from droughts occur as a consequence of the biophysical impacts on the economy as a whole, that is, through changes in resource-based activities on the rest of the

economy. They hence often occur later than direct costs. These include increased unemployment, changes in prices of food and timber, trade losses, reduced tax revenues, and losses in economic sectors indirectly related to droughts (e.g. food industry). Intangible costs of drought denote non-market costs associated with environmental, health and social impacts of droughts. Environmental costs of droughts embrace damage to wildlife and fish habitat, animal disease, loss of biodiversity, loss of wetlands, deteriorated water and air quality, reduced quality or loss of recreational sites, and aesthetic impacts. Health costs primarily refer to an increased risk of diseases, malnutrition and famine due to food shortages. Finally, droughts cause social intangible costs, such as loss of human lives, migration (usually from rural to urban areas), social conflicts, changes in income distribution, and social welfare losses due to restrictions of water supply in households (e.g. prohibition of water use for swimming pools, gardens or car washing).

Some of the methods for drought cost assessment serve for estimating only one cost type (e.g. only intangible costs), while others may be applied to assess two or even all three types of drought damage costs. In addition, some of the methods can assess drought costs only once a drought has occurred (ex post costs), while others allow cost assessment of both a historical and a future or hypothetical drought (ex post and ex ante costs, respectively). Table I provides an overview and comparison of available methods for estimating different types of drought costs along with some of their main characteristics. These include complementarity between different methods, type of drought cost that can be assessed with the method, expected precision of the method, ability to deal with future climate change risks, data needs and availability, and required financial and human resources.

2.1 Market valuation techniques

If possible, economists generally prefer to use direct, observable market interactions for placing a monetary value on goods and services (NOAA, 2011). Various methods are consistent with this market valuation approach. These include using the prices of goods and services which are being traded in markets, a production function approach, assessing costs of avoided damages, and determining replacement or repair costs of damages.

The market price method estimates the economic value of any product or service that is bought and sold in commercial markets. It can be used to value changes in the quantity or quality of a good or service. The estimation starts with assessing the quantity people purchase at different prices and the quantity supplied at different prices. In the case of quality change, one observes a change in market demand function for a good or service and a change in benefits or losses of producers. This information is then used to estimate consumer and producer surpluses. The sum of these represents the total net economic benefit of a good or service in a market. For example, direct costs of a drought in agriculture can be assessed by observing the quantity of crops lost due to a drought and their market prices (or a shift in demand because of deteriorated quality). Based on this information, one can estimate consumer and producer surpluses before and after the event. The difference represents the crop production costs due to drought.

Table I. Overview of the main characteristics of drought cost assessment methods.

	Characteristics Method	Type of method	Complementarity between methods	Type of drought cost addressed	Expected precision	Ability to incorporate future climate change risks	Types of data needed	Data sources	Effort and resources required
1.	Market prices, replacement, repair, or avoided costs, production function	Market valuation techniques	Market valuation methods are often substitutes for one another	Direct and indirect	Good	Yes	Prices and quantities of goods and services sold and bought in markets; production function (output and parameters of production factors); avoided cost (difference between actual cost and potential cost without improvements); cost of replacing or repairing a good or service	Markets for a good or service; private companies; statistics office; government agencies; researcher's estimates	Medium
2.	Assessing effects on GDP and agricultural production	No clear category	Can use results of methods 5, 6 & 7 as inputs	Direct and indirect (very limited) costs	Poor	Unclear	Share of agriculture in GDP and fall in agricultural GDP due to drought	Statistics office	Low
3.	Input-output analysis	Systems approach	Substitute for method 4	Especially useful for indirect costs	Good (depending, among others, on sector disaggregation)	Yes	Input-output tables	Statistics office	Medium
4.	Computable general equilibrium analysis	Systems approach based on a market(s) model	Substitute for method 3. Can use results of methods 5, 6 & 7 as inputs	Especially useful for indirect costs	Good (depending, among others, on disaggregation level)	Yes	Input-output tables, matrices of trade, taxes, input factors, stock changes, various elasticities, etc.	Statistics office; researcher's estimates; estimates from the literature	High
5.	Biophysical-agro-economic modeling	Integration of physical and economic models	Substitute for methods 6 & 7	Direct and (some) indirect costs	Good	Yes	Biophysical (soil, erosion, crop yield, climatic) and socio-economic data	Previous research; FAO; meteorological office; statistics office	High
6.	Coupled hydrological-economic modeling	Integration of physical and economic models	Substitute for methods 5 & 7	Direct, (some) indirect and (some) intangible costs	Good	Yes	Hydrologic and economic data	Previous research; water providing companies; water resource management; statistics office	High

7.	Ricardian hedonic price modeling	Revealed preference method	Substitute for methods 5 & 6	Direct costs	Reasonable	No	Meteorological data, land/farm values and characteristics. economic data	Meteorological office; census or survey; statistics office	Medium
8.	Contingent valuation	Stated preference method	Substitute for methods 9 & 10	Intangible costs	Reasonable	Yes	Stated willingness to pay, demographic and socio-economic data, preferences, environmental conditions	Questionnaire; statistics office; meteorological office	High
9.	Choice experiments	Stated preference method	Substitute for methods 8 & 10	Intangible costs	Good (although difficult to execute well)	Yes	Goods/services with different attributes and prices, demographic and socio-economic data	Questionnaire; statistics office	High
10.	Life satisfaction analysis	A sort of stated preference method (eliciting subjective well-being)	Substitute for methods 8 & 9	Intangible costs	Reasonable (little experience so far and therefore also difficult to judge)	Possibly yes, but hypothetical situations not addressed yet with this method	Meteorological data, individual life satisfaction and demographic data	Meteorological office; surveys on life satisfaction, wellbeing or quality of life	High if data have to be generated through questionnaires; Medium if data already exists
11.	Benefit or value transfer	An aggregation or transfer of previous primary studies	Substitute for stated or revealed preference methods 7, 8 & 9, and possibly also 10	Intangible costs	Reasonable (depends partly on availability of good similar previous studies)	Yes, to a limited extent (depending on the range of primary studies)	Values of a similar environmental good or service obtained by previous studies in a similar context	Previous studies using valuation techniques for the same environmental good or service	Medium (High if done using meta-analysis of primary studies)

A production function approach estimates a function that specifies the output of a company, an industry or the whole economy based on the combination of inputs, i.e. the factors of production. It takes the form $Q = f(L, K, E)$, where L denotes labour, K capital and E an environmental indicator. As factors of production, raw materials and environmental inputs are used in the production of other goods. Assuming that we know the algebraic form of the production function and the parameter values, we can introduce a change in the environmental input (e.g. a deterioration of water quality) and estimate its effect on the output in monetary terms (e.g. a decline in the production of a fishing industry or higher costs of its production). An important limitation of this approach is that production functions are often not known as precisely as needed for applying this technique. In addition, this approach is limited to those resources that are used in the production of goods and services sold in markets.

The avoided cost approach is a closely related technique. Here the production function has the form $Q = f(L, K, E, A)$, where A stands for some 'averting' input. In the case of a change in environmental input, expenditures can be made to mitigate or compensate its negative effects (i.e. by irrigating rain-fed agricultural land which is being subject to a drought). The value of the less water available to agriculture due to a drought can then be valued in terms of expenditure on irrigation (A).

A replacement or repair cost approach assumes that the costs of replacing or repairing an ecosystem good or service represents a reasonable estimate of its value. An example is assessment of the cost of soil erosion due to a drought by estimating the costs of physically recovering and replacing lost soil, nutrients and water.

Studies that have used market valuation techniques (by estimating consumer surplus) for assessing losses caused by rationing policies during drought include Woo (1994), Garcia-Valiñas (2006) and Grafton and Ward (2008). As we will see later in Section 3, market valuation approaches have seen more applications for estimating the costs/benefits of drought adaptation measures than assessing drought damages. Precision of the estimates depends largely on the parameters included in the analysis and a type of model applied. If the approach is applied correctly, the estimate precision is expected to be quite good.

2.2 Assessing effects on GDP and agricultural production

An approach developed by Benson and Clay (1998) explores the relationship between a drought and the economic performance of a country. More specifically, it compares a change in real GDP (Gross Domestic Product) of the agricultural sector and a change in the total GDP of a country for a year in which a drought occurred with a year prior to drought. The authors have used it to study the role of the economic structure of a country on the sensitivity to drought in order to suggest structural adjustments to reduce drought vulnerability. Even though the method is not very precise, it can provide insight into the magnitude of indirect effects. Namely, if a fall in agricultural GDP is higher than a fall in the total GDP of a country, it implies that the economy is predominantly agrarian and that drought principally affects the agricultural sector, having smaller effects on other economic sectors (i.e. indirect effects are relatively small). Similarly, if the total GDP of a country experiences a stronger decrease than the agricultural GDP, drought is likely to adversely affect not only agriculture but also other sectors. It means that the indirect effects are relatively high. The expected precision is poor because factors other than drought that could lead to a

decrease of GDP are not taken into account and the underlying assumptions of the method are not very clear. Moreover, this approach does not distinguish between drought effects on different sectors of the economy apart from agriculture. Finally, care should be taken to not interpret GDP changes as welfare effects.

2.3 Input-output analysis

The input-output data describe the flows of products from each industry to each industry, final demand (such as personal consumption, government expenditures, and exports), and value added for a particular period of time, usually a year (Miller and Blair, 2009). The latter comprises expenditures on labor and capital, taxes, and imports. Based on this information, it is possible to analyze the effects of a change in a price, output, final demand, or value added elements of one or several economic sector(s) on the rest of the economy. In the context of droughts, this approach is particularly useful for assessing the indirect costs of droughts, i.e. the spillover effect of the losses in agriculture and water-providing sector on the rest of the economic sectors. Input-output analysis can be seen as a substitute approach for the computable general equilibrium analysis, discussed in Section 2.4. The advantage of the input-output model is that it is easier to apply and can include a very disaggregate sector structure. However, it also implies more restrictive assumptions regarding factor substitution and technology. Its precision depends mainly on the level of disaggregation of both sectors and regions. Studies that have assessed indirect costs of droughts by using input-output analysis are Martin-Ortega and Markandya (2009) and Pérez y Pérez and Barreiro-Hurlé (2009). Input-output analysis has also seen some application in studying effects of different water policies. For instance, Llop (2008) used the method for evaluating the impact of alternative water policy scenarios on production and consumption prices, intermediate water consumption and private real income. Velázquez (2006) applied the input-output model to determine which economic sectors in Andalusia consume the greatest quantities of water. The model also allows simulation of effects of different policies on water consumption and distribution among sectors.

2.4 Computable general equilibrium analysis

A computable general equilibrium (CGE) model represent one of the most sophisticated types of economic models, which is used for examining the economy-wide impacts of a change in a policy (e.g. a tax reform, a change in trade, energy or agricultural policies), technology, exports, or other exogenous factors. CGE models are based on the assumptions of optimizing behavior of consumers and producers and market clearing. Moreover, product and factor markets are assumed to be competitive. This method can simulate the effects of a drought on the outputs and employment in different sectors of the economy at the regional or national level. The advantage of a CGE approach in comparison with other approaches is that it incorporates economy-wide feedbacks (including interaction between markets, income formation and spending effects, and input and output substitution) in examining different impacts on various sectors, thus allowing an assessment of total (both direct and indirect) effects. As in the input-output analysis, the precision depends on the disaggregation level. In a drought context, both approaches will be more precise and reliable if resource-based (water-using) sectors like agriculture, hydro-electricity, water transport and (drinking) water provision are well demarcated and disaggregated, and the interactions of these activities

with the other activities are accurately captured in the input-output table. Studies that applied CGE models with the aim of estimating drought costs include Islam (2003), Horridge et al. (2005), Berritella et al. (2007), Boyd and Ibararán (2009), Pauw et al. (2010), and Wittwer and Griffith (2010). Salami et al. (2009) apply a slightly different approach (integrated linear programming and macroeconomic modeling), which obtained very similar results to those derived from the CGE models.

2.5 Biophysical-agroeconomic modelling

Biophysical-agroeconomic models integrate crop biophysical models with agro-economic models, providing a comprehensive insight into the feedback effects between human activities and natural resources. In biophysical-agroeconomic models crop physiology models are forced with climate scenarios (temperature-precipitation inputs) from hypothetical or historical droughts. They provide biophysical estimates of crop responses to climate events (yield, water and nutrient use). Therefore, this approach serves to predict how drought conditions affect crop yields and water use. The simulated yield estimates are then incorporated into socio-economic models, usually first for predicting farm-level decisions, which are then aggregated to market levels to predict changes in supply, prices, and economic welfare. The detailed disaggregation level makes its estimates precise. On the other hand, modeling interactions between crop physiology, climate conditions and economic factors is too complex to be very precise. Applications of this method are found in Kulshreshtha and Klein (1989), Rosenberg (1993), Holden and Shiferaw (2004), and Fischer et al. (2005).

2.6 Coupled hydrological-economic modelling

A coupled hydrologic–economic model consists of a hydrological model and an economic optimization model. It serves to analyze the impacts of water allocation and water use by different sectors (not only agriculture as in the previous section) under alternative policy scenarios. The model usually has three components: (1) economic factors, including the cost of water and profits generated by its use, (2) hydrological factors, and (3) institutional factors that affect hydrologic and economic components. Hydrological-economic models are particularly useful decision-support tool for local, regional, or national authorities and agricultural stakeholders. They simulate hydrological impacts of drought rather precisely. Translating the results of hydrological model into economic losses should provide a relatively good estimates of the damages, although they might not take into account the marginal values of water availability. Examples of the studies that applied such models for assessing drought costs include Booker (1995), Booker et al. (2005) and Ward et al. (2006).

2.7 Ricardian hedonic price modelling

Ricardian hedonic price analysis measures the effect of climate on economic welfare. Building on the Ricardian model of land value, this approach links variations in land values across space with variations in climate. Land value is usually a good indicator of economic welfare because it reflects the present value of future streams of net revenues. However, although a disastrous event usually decreases, sometimes it can also increase asset values, making such valuation more complex. The Ricardian approach can be considered as a form of hedonic price method, in which the price of a marketed good is related to its characteristics or the services it provides. The hedonic

price method is used in environmental economics and is predominantly applied to variations in housing prices that reflect the value of local environmental. Ricardian hedonic price modeling uses the same principle with the aim of explaining variations in agricultural land prices by variations in climate conditions (temperature, rainfall). Regarding its precision, as climate is not the only factor that varies across space, the researcher has to control for variation due to other causes, such as soil characteristics, population density, altitude and latitude. However, not all variables can be perfectly measured and controlled for, which can bias the results. The same holds for the omitted variables. In addition, variations in land value can only explain damages in the agricultural sector, meaning that the approach cannot estimate any other costs of droughts apart from agricultural losses. Easterling and Mendelsohn (2000) applied the approach in the context of drought cost assessment.

2.8 Contingent valuation

The contingent valuation method (CVM) is a widely used approach for estimating economic values for all kinds of environmental goods and ecosystem services which are not traded in the market and thus have no market price. It can therefore be applied for estimating intangible costs of drought. CVM is typically used to estimate the benefits (or costs) of a change in the level of provision (or in the level of quality) of a public good. It is also referred to as a stated preference method because it asks people in a survey to state how much they would be willing to pay for a (change in) specific environmental service. It is further possible to ask people what is the amount of compensation they would be willing to accept to give up an environmental service, although the first approach is more recommendable. A contingent valuation survey should include (1) a detailed description of a good being valued and the hypothetical change regarding the good, (2) questions about willingness to pay (WTP) for a good being valued, and (3) questions about respondents' characteristics (age, income, education) and preferably their preferences concerning the good. An advantage of CVM (and other stated preference techniques, like choice experiments; see Section 2.9) over revealed preference techniques (like hedonic price, travel cost and Ricardian modeling methods) is that it can address hypothetical changes in policy, that is, policy changes which are considered but have not (yet) been implemented. The main disadvantage is that data generated by CVM (and other stated preference techniques) are hypothetical. Because of this most economists tend to assign more credibility to revealed preference techniques which use data about actual, past choices by individuals in markets. This approach usually provides rather reasonable estimates, even though the main problem in assessing its validity is the absence of actual values against which to compare the results. However, validity of the WTP can be tested by comparing the result with those from other valuation studies using other methods, the finding of the cross-study analyses (e.g. meta-analyses or benefits transfers), or simulated markets. Such comparisons often show that CVM is likely to slightly overestimate the actual value due to its hypothetical nature. Validity can also be evaluated by examining consistency of CVM estimates with expectations derived from economic theory (e.g. a positive relationship between stated values and the respondent's disposable income). CVM has mainly been applied to estimate the value of avoiding water use restrictions or increasing the security of water supply (Bakarat and Chamberlin, Inc., 1994; Howe et al., 1994; Griffin and Mjelde, 2000; Koss and Khawaja, 2001). In addition, Pattanayak

and Kramer (2001a) used it to estimate the value of drought mitigation provided by tropical forest watersheds. More generally, contingent valuation can be used to assess the costs of drought damage, mitigation or adaptation, including foreseen or hypothetical measures.

2.9 Choice experiments

Choice experiments (CE) are, along with the contingent valuation method (CVM), important tools for valuing non-market goods, i.e. intangible costs of drought. They represent a more recent approach which offers several advantages over CVM. For example, respondents are more familiar – through participating on an almost daily basis in market transactions – with making a choice for a good that has a range of characteristics of which price is one, rather than stating a price they would be willing to pay for that good. Moreover, CE enables estimating the value of the individual attributes that make up an environmental good, and they avoid some of the biases associated with CVM. In a choice experiment, individuals are asked to choose among several alternatives in a choice set, and they are usually requested to perform a sequence of such choices. Each alternative is described by a number of attributes or characteristics. A monetary value is one of the attributes, which enables estimation of the WTP. CE is, however, generally more difficult to execute than CVM, especially if the number of attributes is large. Like contingent valuation, it suffers from hypothetical bias. Its precision depends mainly on the design of the experiment, which involves the definition of attributes and their levels, the context of the experiment, and questionnaire development. Most analyses of CE validity (although there are relatively few) arrive at a positive judgement. Despite its advantages over CVM, there seems to be only one CE application related to drought cost estimation (Hensher et al., 2005 and Hensher et al., 2006). Like CVM, CE can be used to assess the costs of drought damage, mitigation or adaptation, including foreseen or hypothetical measures.

2.10 Life satisfaction analysis

Life satisfaction (also referred to as happiness or subjective well-being) research is emerging as an important approach to elicit preferences within many disciplines (e.g. psychology, sociology, economics). Asking people to assess their current level of happiness has become a regular feature of public surveys. These subjective data can then be used jointly with objective data on per capita income, other socio-economic indicators, and environmental conditions, for example, to examine how self-reported well-being varies with prosperity, life styles and environmental quality. Econometric modeling such as regression analysis is applied to analyze subjective well-being data. Coefficients from the model are then applied to calculate the income-equivalence changes (i.e. losses/benefits) due to a change in self-reported life satisfaction. This is a crucial step for the precision of the approach and depends primarily on the quality of the model. However, life satisfaction analysis has seen very few applications in a drought context. For this reason, its precision in this research area is difficult to judge. There seems to be only one study that relates life satisfaction data with rainfall data for Australia (Carroll et al., 2009). Nevertheless, we do not see obstacles for a more widespread use of this approach in estimating intangible costs of droughts.

2.11 Benefit or value transfer

Non-market valuation methods require a survey, which can be costly and time-consuming. Hence, the benefit (or value) transfer method was developed for situations in which the funds and/or time available for data collection are constrained. In this method, monetary values of environmental good or service estimated at one site (study site) are spatially and/or temporally transferred to another (policy) site. The study site refers to the place where the original study took place, while the policy site is a new site where information is needed about the monetary value of similar good or service. The transfer can be done by simply applying a benefit estimate obtained from a similar study to the current case study (benefit estimate transfer), by inserting characteristics of the current case study instead of the characteristics used in the original study into the econometric model (benefit function transfer), or by constructing a dataset based on a larger number of previous studies and regressing environmental benefit measures against study characteristics (meta-analysis). Brouwer (2000) provides an overview of the environmental value transfer approach, discusses its potential role in cost-benefit analysis as a decision-support tool and develops guidelines for its proper application. He argues that this method often results in substantial transfer errors, which could be diminished if one would follow strict guidelines for quantitative adjustment mechanisms, especially taking into account differences in the very nature of the values elicited (such as, the diversity of motivations underpinning valuations or the historical-cultural and policy context in which they are elicited). Benefit or value transfer method is particularly useful for estimating intangible costs of drought. For example, Martin-Ortega and Markandya (2009) used the approach for estimating the welfare loss due to worsening of environmental quality and water supply restrictions for households during a drought event in Barcelona. The value estimates were in this case transferred from a choice experiment of the Serpis river basin in Spain.

3 DROUGHT MITIGATION AND ADAPTATION POLICIES AND THEIR COST ASSESSMENT

Two main types of government responses to drought can be distinguished: pre-impact interventions for drought impact reduction and post-impact government interventions. The former set of measures represents risk management because the undertaken measures are proactive, being aimed at mitigating the future effects of drought, increasing coping capacity and building resilience. Examples of such measures include development of an early warning system, preparedness plans, increased water supply, demand reduction (such as water conservation programs), and crop insurance against droughts. Even though these measures are available, some of them have hardly seen any implementation (e.g. insurance against droughts), while others have much more potential than what has been used so far. For instance, to reduce water demand some of the existing (unsustainable) practices of water use could be reconsidered or at least stricter standards of water consumption for such activities could be set, particularly in arid areas. Examples include numerous golf courses, swimming pools and aqua parks for tourism purposes in the Mediterranean regions and intensive agriculture based on irrigation (e.g. in Almeria, Spain). In addition, it is important to determine priorities of water uses for periods of water shortages. In relation to pre-impact interventions, important measures which have not received much attention in the literature are developing measures that ensure (the recovery of) good environmental conditions (e.g.

wetlands, aquifers), more flexible water concession systems (such as exchanging centers and assignment contracts in Spain, which enable buying water rights from the agricultural sector for urban uses), and increasing water recycling.

Post-impact government interventions include crisis management. Such programs are reactive since measures are implemented after a drought occurs and focus on treating the symptoms instead of the causes of the natural hazard. They include drought relief funds, low-interest loans, transportation subsidies for livestock and livestock feed, provision of food, water transport, and drilling wells for irrigation and public water supplies (Wilhite, 2000). The latter drought management approach has been criticized by scientists, government officials, and many relief recipients as inefficient, ineffective and untimely (Wilhite, 1993). In addition, the provision of emergency relief has been criticized as being a disincentive to the sustainable use of natural resources because it does not foster self-reliance (Bruwer, 1993; White et al., 1993). Such measures can actually increase vulnerability to droughts as well as other natural hazards. For this reason, it is more recommendable to undertake proactive mitigation programs aimed at reducing vulnerability to, and thus the future impacts of, droughts.

Most drought mitigation and adaptation measures are complementary, that is, they all help in reducing different risk types and are important at different stages of drought evolution. Furthermore, drought mitigation and adaptation policies should be set for a long term (at least 20 years in the future). In this way, impacts of infrequent drought events are taken into account, and one can incorporate the projected impacts of climate change more easily. Otherwise, no effects of climate change are 'observable' within the time frame of a preparedness plan and thus there is no incentive to invest in drought prevention, mitigation or adaptation. In addition, it is important to ensure participation of local communities in decision-making and water planning, since access to water represents a basic human right and should thus not be completely driven by market rules. In this way, a feeling of co-responsibility for mitigating drought impacts is likely to develop. For instance, the social impacts of droughts depend greatly on people's tolerance to, i.e. capacity to live with, less water during a drought period and their willingness and capability to change their habits.

Many of the costs of drought mitigation and adaptation policies are direct costs which have market values and are thus rather easy to estimate. For example, costs related to monitoring and early warning systems mainly include research and development, engineering, investment and maintenance costs. These types of costs usually relate to physical impacts that are associated with market prices. Hence, the appropriate methods for assessing such costs of drought mitigation and adaptation measures include market valuation techniques explained in Section 2.1. Construction of new infrastructure for increasing water supply also represents direct costs that can be valued at market prices. However, it can have detrimental impacts on social welfare due to their impacts on land fragmentation and aesthetics. On the other hand, it may be a potential source of benefits by allowing for more recreational activities. Appropriate methods for estimating such non-market costs and benefits are stated or revealed preference methods, some of which are explained in Sections 2.8 to 2.11. In addition, input-output analysis and CGE (Sections 2.3 and 2.4) can serve as useful methods for exploring the potential effects of alternative water-related policies. Finally, multi-criteria analysis can be a useful decision-making tool when choosing between different policy options because it allows for a systematic comparison of the multiple impacts of

alternative policies. Rossi et al. (2005) used this method for selecting the preferable mix of drought mitigation measures related to a water supply system in eastern Sicily, Italy. Their results confirm the applicability of multi-criteria analysis for a transparent comparison of drought mitigation measures and its relevance for the decision making process.

It is generally agreed that mitigation and preparedness are key to reducing future drought risks. However, government officials are often reluctant to implement policies and invest (financial) resources to mitigation because of limited information on the costs and benefits of drought mitigation programmes (Ding et al., 2010). There are very few studies that try to assess the costs of drought prevention, mitigation or adaptation measures. Some of them include Michelsen and Young (1993), Woo (1994), Fisher et al. (1995), Pattanayak and Kramer (2001a; 2001b), Morton et al. (2005), and Grafton and Ward (2008).

It would be useful to compare the costs of drought mitigation and adaptation policies with the costs of drought prevention and the costs of potential or historical drought. In such analysis special attention should be given to the emergency costs, which can vary significantly depending on the adopted baseline. Since they may apart from temporary measures (e.g. drought relief programmes) include investments in infrastructure that will serve for the next several decades, it is important to set a baseline which will determine the share of these costs corresponding to drought damages and those related to drought mitigation policy. Moreover, assessment of drought mitigation and adaptation measures should include transaction costs of enforcing a new policy. This may also shed light on the cost-effectiveness of some existing practices (e.g. in agriculture). For example, it might prove to be less costly to invest in an irrigation system than to subsidize farmers or offer them a drought relief programme. The US Federal Emergency Management Agency (FEMA) estimated that the country will save at least two dollars on future disaster costs from every dollar spent on mitigation (Natural Hazards Observer, 1996).

4 RECOMMENDATIONS AND CONCLUSIONS

This article has examined available methods for assessing the costs of drought and related policies. At a general level, drought costs can be classified into drought damage costs and costs of drought mitigation or adaptation policies. In addition, damage costs can be decomposed into direct, indirect and intangible costs.

Of all the methods for assessing the costs of droughts presented in this article, we consider computable general equilibrium (CGE) analysis as the most complete method for assessing direct and indirect costs of drought because it takes all sectors and markets of the economy into account. Nevertheless, as these costs might as well be estimated using a less demanding approach, a tradeoff between the advantages and the effort required to apply this method should be carefully considered. For example, the input-output analysis is simpler but also somewhat less precise. Biophysical-agro-economic modeling is rather complex and provides an in-depth analysis of agricultural markets, but its drawback is that it is limited to the agricultural sector. The same holds for Ricardian hedonic price modeling, which focuses on agriculture. Nevertheless, usually the largest share of the direct costs caused by droughts is experienced in the agricultural sector, in which cases these approaches represent a good

practice, that is, if only direct costs are to be estimated. Coupled hydrological-economic modeling is limited to assessing drought costs which are directly related to water use. Different methods could hence function in a complementary way, where the biophysical-agroeconomic and Ricardian hedonic price modeling approaches would provide more details and possibly inputs to CGE analysis. The main disadvantage of the majority of the mentioned methods is that they demand a lot of data and good formal (and applied) modeling skills. Assessing direct and indirect costs of droughts by observing a change in GDP and agricultural production of a country is useful for indicative purposes, but may provide less reliable cost estimates than other discussed methods.

A choice between the methods for estimating intangible costs of droughts is less clear. Contingent valuation (CVM) and choice experiments (CE) can be used as alternative, substitute methods for eliciting individuals' willingness to pay and are expected to arrive to similar estimates. Recently, CE has become more popular due to several advantages over CVM, explained in Section 2.9. However, it also has some drawbacks. The technique is much more demanding for respondents than CVM, preferences may be inconsistent in the experiment, the design of CE is a non-trivial task, and its precise incentive properties are still not very clear. Life satisfaction analysis can be regarded as a substitute approach to both CVM and CE. Nevertheless, CVM and CE are often used for calculating hypothetical or future changes, while life satisfaction analysis has only been applied to current or historical situations.

A shift from post-impact interventions towards more effective pre-impact drought mitigation policies is needed. The latter include early warning systems, drought preparedness plans, increased water supply, water demand reduction and crop insurance against droughts. Some of these policies have already been widely used in different regions, while others have not yet been implemented anywhere except in pilot projects (e.g. insurance). Moreover, some measures are able to achieve much more ambitious objectives than have been realized until now (e.g. water demand reduction). Therefore, there is higher potential capacity for drought mitigation and adaptation in coping with climate change compared to what has been used so far. Apart from such measures which are commonly considered in the drought literature, there are other ones which deserve more attention in future research. These include recovery of good environmental conditions (e.g. recovery of wetlands and aquifers), establishment of exchanging centers and assignment contracts for water use rights, and water recycling and reuse. Recovery of good environmental conditions enables resilience of the system to droughts. It implies that environmental policy plays a substantial role in the mitigation of droughts. Through exchanging centers the water authorities can make takeover bids of concession rights to water in order to reallocate them or to achieve a sustainable rate of use. Thus, in the case of anticipated or increasing water shortages water authorities can buy concession rights on water for irrigation from farmers and allocate these among urban users. In this way, agriculture can serve as a buffer when a drought occurs, absorbing a great part of the drought risk. Finally, a combination (set) of measures is recommendable since it ensures better risk distribution and has a synergetic value.

It is recommendable to set drought mitigation and adaptation policies for a long term, i.e. 20 or more years in the future. This enables taking into account effects of predicted climate change and a change in the frequency of droughts. Both phenomena

are difficult (and sometimes even impossible) to observe in the short term. Moreover, enabling participation of local communities in decision-making processes, policy design and planning may play an important role in mitigating and adapting to droughts.

With respect to the costs of drought prevention, mitigation and adaptation, market valuation techniques seem to be the most appropriate choice if market prices are available. Otherwise, non-market (stated and revealed preference) valuation techniques can be used. Methods such as input-output analysis, computable general equilibrium analysis, and multi-criteria analysis can serve as useful decision-making tools when choosing between several alternative policies. In general, drought policy should be based on good planning. It is recommendable that planners conduct a cost-benefit analysis in which damage costs of a (potential) drought are compared to the costs of mitigation and adaptation measures. Finally, there is a need for a comprehensive cost-benefit analysis of various drought mitigation and adaptation policies. Further research is also needed concerning the distribution of drought costs – and to a lesser extent benefits – among economic sectors and social actors.

Acknowledgments. The authors thank the partners in the EU 7th Framework Programme project ConHaz (Costs of Natural Hazards) and the participants of the drought expert workshop “Assessing the Costs of Droughts” (held February 2011) for their valuable comments and suggestions.

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