Nat. Hazards Earth Syst. Sci., 13, 2599–2603, 2013
www.nat-hazards-earth-syst-sci.net/13/2599/2013/
doi:10.5194/nhess-13-2599-2013

Natural Hazards and Earth System Sciences
Open Access

Preface

"Weather-related hazards and risks in agriculture"

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Abstract. In many parts of the world, weather represents one of the major uncertainties affecting the performance and management of agricultural systems. Due to global climate change, the climatic variability and the occurrence of extreme weather events is likely to increase leading to a substantial increase in agricultural risk and destabilisation of farm incomes. The aim is to discuss the state of the art research in the area of analysis and management of weather-related risks in agriculture. Weather-related risks in agriculture are important not only for farm managers but also for policy makers, since income stabilisation in agriculture is frequently considered as a governmental task.

Since record keeping began in the late 1800s, many temperature records have been broken. A spring heat wave like no other in US and Canadian history peaked in intensity during March 2012. Many temperature records have been measured in the year 2010 in 17 countries including Pakistan, where 53.5 °C was recorded. Pakistan not only faced high temperatures, but also devastating floods that made more than four million people homeless and in vast areas reduced the crop harvest to zero. In Russia, temperatures of 40 °C were reached during the summer of 2010 and the resulting drought caused vast forest fires for weeks. These were responsible for hundreds of human deaths, and covered Moscow and its environs with toxic smog for weeks. Extreme reductions of soil moisture induced wheat yields in Russia, Ukraine and Kazakhstan to decline by over 40 % in 2010. Increases in air and surface water temperatures, and sea level rises threaten the very existence of small island states, whereas conversely Arctic sea ice, glaciers and spring snow in the Northern Hemisphere have decreased. At the same time Europe experienced its hardest winter since the 1940s. Even when none of these individual events can be attributed to human induced climate change, they provide a picture of extreme weather events and their impact on human livelihood including agriculture.

Hazard and disaster can be ranked according to impact criteria, and the probability of a hazardous event can be placed on a scale from zero to certainty (0 to 1). The relationship between a hazard and its probability can then be used to determine the overall level of risk. Risk is sometimes taken as synonymous with hazard, but risk has the additional implication of the statistical chance of experiencing a particular hazard (Pflug et al., 2007). Hazard is best viewed as a naturally occurring, or human-induced, process or event with the potential to create loss (i.e. a general source of future danger). Risk is the actual exposure of something of human value to a hazard and is often measured as the product of probability and loss (Smith, 2009).

Searching through the SCOPUS database, the terms "agriculture" + "risks" + "hazards" in the title, abstracts or keywords of scientific journals appears for the first time in 1974, in the article titled "Unity and diversity in landscape" by Tjallingii (1974) which regards ecological units as grouped micro-, meso- and macro-units based on comparisons of soil maps and vegetation maps. The author using these comparisons elaborated on diversity and structure diversity maps. As the irreplaceable character of a given area determines its importance for nature conservation and nature design functions, the differentiation value maps can be translated into a vulnerability map, indicating the risk for irreparable damage in case of radical changes, such as towns, road building, agriculture practices, etc. The number of published works on these terms

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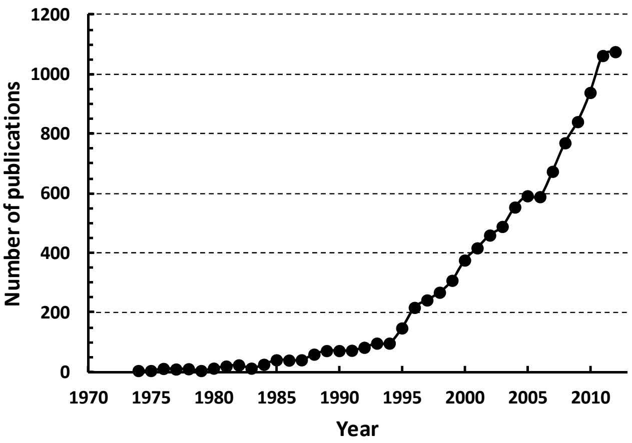

Fig. 1. Number of manuscripts published on "hazards" + "risk" + "agriculture" terms from 1970 to 2012 recognised in SCOPUS database.

has increased dramatically since 1990 (see Fig. 1) pointing to the importance of these issues in the scientific world. In 1990 the number of articles was 72 and in 2012 the number reached 1076, almost 15 times more.

Risk management is part of a farmers' business strategy since production is subject to many uncertainties that could threaten returns or even the viability of farms. The sources of risk in agriculture are numerous and diverse. A diversity of hazards related to weather determines production in ways that are outside the control of the farmer. The prevalence of sources of risk that affect many farmers at once, such as weather-related hazards, is specific to agriculture. Some weather related risks such as drought and floods have a systemic component in that they affect most farmers within an entire region or country. Others such as storms are more location specific. Agriculture as an economic sector is therefore most vulnerable and most exposed to climate extremes

Most studies model the impact of changes in mean values of weather variables and few models have so far incorporated the impact of increased frequency of extreme events and weather variability on production. Over the last decades, a wide range of methodologies using different metrics, time periods, and assumptions has been developed and applied for assessing adaptation costs and benefits. However, much of the literature remains focused on gradual changes such as sea level rise and effects of long-term means in precipitation and temperature on agriculture (IPCC, 2007). Recent studies, however, indicate that climate change scenarios that include increased frequency of heat stress, droughts and flooding events reduce crop yield and livestock productivity beyond the impacts due to changes in mean variables alone. From the point of view of risk management, however, it is not the structural long-term changes that may result from climate change that are of interest, but the extent to which variability will be affected. Production variability is likely to increase due to more frequent extreme weather conditions or events (at least at the individual farm level).

The 2012 Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) from the Intergovernmental Panel on Climate Change focuses on the relationship between climate change and extreme weather and climate events, the impacts of such events, and the strategies to manage the associated risks (IPCC, 2012). Understanding of extreme events and disasters is a pre-requisite for the development of adaptation strategies in the context of climate change and risk reduction in the context of disaster risk management. Extreme events will have greater impacts on sectors with closer links to climate, such as agriculture and food security. Research reports since 2010 show evidence that the current warming trends have begun to negatively impact agriculture through an increase in the probability of extreme temperatures during the growing season.

Effective risk management involves anticipating possible difficulties and planning to reduce their consequences, not just reacting to unfavourable events after they occur. The two primary aspects of risk management are first anticipating that an unfavourable event may occur and acting to reduce the probability of its occurrence and second taking actions which will reduce the adverse consequences should the unfavourable event occur. Both structural and non-structural measures are important to reduce the impact of climate variability including extreme weather on crop production (Lobell, 2011). While the structural measures include strategies, such as irrigation, water harvesting, windbreaks, etc., the non-structural measures include the use of the medium-range weather forecast and crop insurance.

This Special Issue consists of a selection of eleven papers based on the talks given at the European Geosciences Union General Assembly that took place in Vienna, Austria in April 2010 and April 2011. The talks were presented by the authors at the Natural Hazards Programme Group during the sessions on Assessment of Weather-related Risk on Agricultural Production and Agribusiness (NH1.5/ AS4.5/CL4.13 in 2010 and NH1.7/AS4.6/CL3.6 in 2011). Although the authors investigated different agricultural systems at a variety of scales using a diverse range of mathematical models and techniques, the common theme was to have a better understanding of possible impacts of climate change and weather-related risks on agricultural production, and to evaluate possible options for risk management.

Droughts do not usually have a sudden beginning or end. They are an insidious hazard caused by a period of abnormally dry weather, persisting long enough to produce a serious hydrologic imbalance. Climatic parameters such as rainfall, wind speed, radiation, air temperature and humidity affect the crop water requirements and are susceptible to variations. Moratiel et al. (2011) evaluated the impact of climate change in evapotranspiration in the Duero River basin. In this study they consider the maximum and minimum temperature

(T_{max}, T_{min}), dew point (T_d), wind speed (U) and net radiation (R_n) trends based on 1980–2009 period and extrapolated with the FAO-56 Penman–Monteith equation to estimate ET_o. Four scenarios are contemplated taking into consideration actual and future concentration of CO_2 (372 ppm and 550 ppm) and the period analysed (annual or monthly). The future ET_o estimations showed increases between 118 mm (11 %) and 55 mm (5 %) with respect to the current situation of the river basin at 1042 mm. At the same time, not all the months were equally affected, May, June, July, August and September are the most affected ones, which also coincide with the maximum water needs of the basin's crops. Therefore, an accurate estimation of ET_o is critical as is the main factor affecting the calculation of crop water use. Moratiel et al. (2013) studied the effect of the uncertainty due to random noise in the sensors used for measurement of meteorological variables on the estimation of ET_o, crop ET and net irrigation requirements of grain corn and alfalfa in three irrigation districts of the middle Ebro River basin. The uncertainty in relative humidity and temperature at different irrigation districts Canal were the two most important factors followed by wind speed and solar radiation affecting the estimation of ET_o, corn ET (ET_{c_corn}), alfalfa ET (ET_{c_alf}), net corn irrigation water requirements (IRn_{corn}) and net alfalfa irrigation water requirements (IRn_{alf}). However, this effect was never greater than ±0.5 % over annual scale time. Considering the accuracy for all sensors over annual scale time, the variation was about ±1 % of ET_o, ET_{c_corn}, ET_{c_alf}, IRn_{corn}, and IRn_{alf}. ET_o daily fluctuation remained lower than 5 % during the growing season of corn and alfalfa being within an acceptable range, and it can be considered that the sensor accuracy of the meteorological variables is not significant in the estimation of ET_o.

Another source of variation in evapotranspiration estimations is the high spatio-temporal variability found in climatic variables and soil. This could drive to an inadequate assessment of soil water content in the root-influenced zone and/or soil water consumption by plants. Mestas-Valero et al. (2012) used frequency domain reflectometry (FDR) to quantify the soil moisture dynamics in the root-influenced zone to assess the daily water consumption by the crop. Then they compared it with evapotranspiration estimated by the Penman–Monteith equation using meteorological data from a station located on the experimental site. Their results show that evapotranspiration overestimate maize water requirements presenting values greater than those measured with the FDR probe. The authors concluded that monitoring soil water content to assess saturation risks or water stress (drought) are more accurate for decision making.

At a regional scale, Gobin (2012) applied REGCROP model (Gobin, 2010) to examine changing weather patterns in relation to the crop season and crop sensitive stages of six arable crops: winter wheat, winter barley, winter rapeseed, potato, sugar beet and maize. In this way, a biometeorological condition that affect Belgian arable crop yield can be elected. The single best predictor of arable yield was the sum of vapour pressure deficit during the growing season with R^2 ranging from 0.55 to 0.76 depending on the studied crop. Drought and heat stress occurrence significantly differ between two climatic periods, 1947–1987 and 1988–2008. Gobin (2012) found that though average yields have risen steadily between 1947 and 2008, there is no evidence that relative tolerance to stress has improved.

The increasing reliability of remote sensing methodologies and techniques present a wide range of capabilities in monitoring and assessing droughts and their correlation with meteorological variables and crop yield. Dalezios et al. (2012) used the remotely sensed Reconnaissance Drought Index (RDI) to quantify drought in Thessaly area (central Greece) a drought-prone agricultural region. RDI uses hydrometeorological parameters, such as precipitation and potential evapotranspiration, and enables to assess hydrometeorological drought. Several drought features are analysed and assessed by using monthly RDI images over the period 1981–2001: severity, areal extent, duration, periodicity, on set and end time. Dalezios et al. (2012) show an increase in the surface extent during each drought episode and that droughts are classified small areal extent drought and large areal extent drought. The large ones coincide with the beginning of the hydrological year, whereas the small droughts are in spring. The maximum drought in each episode was found usually in the summer.

Pereira et al. (2011) work focuses on the relation between weather and annual chestnut production to model the role of weather, to assess the impacts of climate change and to identify appropriate locations for new groves. In order to do so a large set of meteorological variables and Normalize Deviation Vegetation Index (NDVI) were computed and their role on chestnut productivity evaluated with composite and correlation analyses identifying variables cluster with an impact on chestnut production. Then, the authors focused on developing multiple regression models to explain a significant fraction of productivity variance obtaining: (i) a simulation model (R^2-value = 87 %) based on the winter and summer temperature and on spring and summer precipitation variables; and, (ii) a model to predict yearly chestnut productivity (R^2-value of 63 %) with five months in advance, combining meteorological variables and NDVI. Goodness of fit statistic, cross validation and residual analysis demonstrate the model's quality, usefulness and consistency of obtained results.

In its 4th Assessment Report, the Intergovernmental Panel on Climate Change found that rising global temperatures are likely to increase the frequency and magnitude of extreme weather events; including prolonged heat waves and more intense rainfall. Weather extremes resulting from climate change are projected to increase, making crop production more vulnerable and ultimately threatening food security (Tarquis et al., 2010). In an effort to develop scientific knowledge in climate and agriculture to help to manage risks, Ruiz-Ramos et al. (2011) and Valencia et al. (2012) present a study on value and frequency of maximum temperatures and extreme rainfall events respectively.

Impacts of current and future high temperatures on cereal cropping systems of the Iberian Peninsula (IP) have been evaluated by Ruiz-Ramos et al. (2012), focusing on vulnerable development periods of winter and summer crops. They combined crop simulation models with climate change scenarios obtained from an ensemble of ten Regional Climate Models (multimodel ensemble) for this purpose and related uncertainty was estimated. Their results show that higher extremes of maximum temperature represent a threat to summer-grown but not to winter-grown crops in the IP. Finally, the effective impact was found to be greater in the IP south but the increase of extreme events was larger in the IP north. The authors point out that this difference was due to a much earlier flowering date in the south.

Some studies developed in Italy and USA have shown that there is a change in seasonal patterns and an increasing frequency of extreme rainfall events, whereas other studies have pointed out that no global behaviour could be observed in monthly trends due to high climatic variability. Valencia et al. (2012) tested which of these scenarios is the case for the Ebro River basin, where these events has had a devastating impact. After a stationarity analysis, the initial studied period was subdivided in 1957–1979 and 1980–2002 in order to analyse the rainfall distribution functions. Their results showed that generalised Pareto distribution (GPD) parameters and the maximum expected return values do not support the results previously obtained by other authors that affirm a positive trend in extreme rainfall indexes.

In Europe, Spain is one of the countries that experience high agricultural losses related to hailstorms. Models that can support calculations of the probabilities of economic losses due to hail damage and of the tendency over time for such losses are of high interest. Some studies, developed in the Netherlands and France, have found significant correlation between summer mean temperature and yearly hail severity index obtained for insurance purposes. At the same time, other studies in the USA point out that a highly significant correlation between both is not possible to find due to high climatic variability. Saa-Requejo et al. (2011, 2012) work focused to test this possible correlation over the Spanish IP. With this purpose, correlation analyses on both variables were performed for the 47 Spanish provinces (as individuals and single set) from 1981 until 2007, and for all crops and four individual crops: grapes, wheat, barley and winter. The result obtained by the authors does not confirm the previously one obtained for France and the Netherlands. For some IP provinces significant relationships were found; however, not all of them were relevant regarding hail incidence. They pointed out that beside the influence by series length, data frequency and the crop considered on this study; a main factor is the differences in the special characteristics of each area's landscape and topography.

There are two manuscripts concern to soil hazards, Lourenço et al. (2012) present a study on soil pollution and Anton et al. (2012) show how to applied multi-criteria decision making (MCDM) to select the optimal rotation to minimise soil erosion and degradation.

Lourenço et al. (2012) found through chemical analysis by atomic absorption spectrometry that the concentration of various toxic elements was higher in roads near the city of Coimbra (central Portugal) than the mean background values for world soils as well as in rivers. Urban pollution and road traffic emission seem to be the main influence for these values. They showed with their results that magnetic measurements carried out on surface soil samples are a sensitive, fast, inexpensive and robust method, which can be advantageously applied for studying soils affected by urban and road pollution.

Extreme rain events, inundations and other severe erosions forming gullies demand urgently actions in agro-areas of Arroyos Menores (La Colacha) to avoid soil degradation and erosion supporting good levels of agro-production. Antón et al. (2012) evaluated the systems of soil uses and actions that should be considered as relevant aspects of the study area. Then, they applied discrete MCDM to choose among global types of use of soils, and later continuous MCDM to evaluate and optimise combined actions, including repartition of soil use and the necessary levels of works for soil conservation and for hydraulic management to conserve against erosion these basins. Relatively global solutions for La Colacha area have been defined and were optimised by linear programming in goal programming forms.

Because of the economic importance of agriculture, its vulnerability to climate change, and its contribution to emissions, building resilience to climate change represents an enormous challenge, even as scientific understanding of the climate system and feedback mechanisms among agriculture, weather, and water and carbon cycles progresses. It is hoped that this volume will act as a vehicle to promote the diffusion of these multidisciplinary approaches and efforts involving more and more scientists of the research community.

Acknowledgements. We are grateful to all the reviewers who donated their time to ensure the quality of the papers. We want to express our gratitude to the Natural Hazards and Earth System Science Journal editor, Fausto Guzzetti, who showed great enthusiasm when we propose this special issue. To the Journal office, thanks so much for your patient and technical help.

References

Antón, J. M., Grau, J. B., Cisneros, J. M., Laguna, F. V., Aguado, P. L., Cantero, J. J., Andina, D., and Sánchez, E.: Continuous multi-criteria methods for crop and soil conservation planning on La Colacha (Río Cuarto, Province of Córdoba, Argentina), Nat. Hazards Earth Syst. Sci., 12, 2529–2543, doi:10.5194/nhess-12-2529-2012, 2012.

Dalezios, N. R., Blanta, A., and Spyropoulos, N. V.: Assessment of remotely sensed drought features in vulnerable agriculture, Nat. Hazards Earth Syst. Sci., 12, 3139–3150, doi:10.5194/nhess-12-3139-2012, 2012.

Gobin, A.: Modelling climate impacts on crop yields in Belgium, Clim. Res. 44, 55–68, 2010.

Gobin, A.: Impact of heat and drought stress on arable crop production in Belgium, Nat. Hazards Earth Syst. Sci., 12, 1911–1922, doi:10.5194/nhess-12-1911-2012, 2012.

IPCC AR4 WG2: Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E., Cambridge University Press, ISBN 978-0-521-88010-7 (pb: 978-0-521-70597-4), 2007.

IPCC: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, edited by: Field, C. B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi, K. L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M., and Midgley, P. M., Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp., 2012.

Lobell, D. B., Schlenker, W., and Costa-Roberts, J.: Climate Trends and Global Crop Production Since 1980, Science, 333, 616–620, 2011.

Lourenço, A. M., Rocha, F., and Gomes, C. R.: Relationships between magnetic parameters, chemical composition and clay minerals of topsoils near Coimbra, central Portugal, Nat. Hazards Earth Syst. Sci., 12, 2545–2555, doi:10.5194/nhess-12-2545-2012, 2012.

Mestas-Valero, R. M., Mirás-Avalos, J. M., and Vidal-Vázquez, E.: Estimation of the daily water consumption by maize under Atlantic climatic conditions (A Coruña, NW Spain) using Frequency Domain Reflectometry – a case study, Nat. Hazards Earth Syst. Sci., 12, 709–714, doi:10.5194/nhess-12-709-2012, 2012.

Moratiel, R., Snyder, R. L., Durán, J. M., and Tarquis, A. M.: Trends in climatic variables and future reference evapotranspiration in Duero Valley (Spain), Nat. Hazards Earth Syst. Sci., 11, 1795–1805, doi:10.5194/nhess-11-1795-2011, 2011.

Moratiel, R., Martínez-Cob, A., and Latorre, B.: Variation in the estimations of ET_o and crop water use due to the sensor accuracy of the meteorological variables, Nat. Hazards Earth Syst. Sci., 13, 1401–1410, doi:10.5194/nhess-13-1401-2013, 2013.

Pereira, M. G., Caramelo, L., Gouveia, C., Gomes-Laranjo, J., and Magalhães, M.: Assessment of weather-related risk on chestnut productivity, Nat. Hazards Earth Syst. Sci., 11, 2729–2739, doi:10.5194/nhess-11-2729-2011, 2011.

Pflug, G. Ch. and RÄomisch, W.: Modelling, Measuring and Managing Risk, World Scientific, 2007.

Ruiz-Ramos, M., Sánchez, E., Gallardo, C., and Mínguez, M. I.: Impacts of projected maximum temperature extremes for C21 by an ensemble of regional climate models on cereal cropping systems in the Iberian Peninsula, Nat. Hazards Earth Syst. Sci., 11, 3275–3291, doi:10.5194/nhess-11-3275-2011, 2011.

Saa Requejo, A., García Moreno, R., Díaz Alvarez, M. C., Burgaz, F., and Tarquis, M.: Analysis of hail damages and temperature series for peninsular Spain, Nat. Hazards Earth Syst. Sci., 11, 3415–3422, doi:10.5194/nhess-11-3415-2011, 2011.

Saa Requejo, A., García Moreno, R., Díaz Alvarez, M. C., Burgaz, F., and Tarquis, A. M.: Corrigendum to "Analysis of hail damages and temperature series for peninsular Spain" published in Nat. Hazards Earth Syst. Sci., 11, 3415–3422, 2011, Nat. Hazards Earth Syst. Sci., 12, 51–51, doi:10.5194/nhess-12-51-2012, 2012.

Smith, K.: Environmental Hazards: Assessing Risk and Reducing Disaster, edited by: Smith, K. and Petley, D. N., Taylor & Francis Group, Florence Production Ltd. Stoodleigh, Devon, United Kingdom, 5th Edn., ISBN: 978-0-415-68106-3, 2009.

Tarquis, A. M., Gobin, A., and Semenov, M.: Agriculture in a changing climate, Preface, Clim. Res., 44, 1–2, 2010.

Tjallingii, S. P.: Unity and diversity in landscape, Landscape Planning, 1, 7–34, 1974.

Valencia, J. L., Tarquis, A. M., Saá-Requejo, A., and Gascó, J. M.: Change of extreme rainfall indexes at Ebro River Basin, Nat. Hazards Earth Syst. Sci., 12, 2127–2137, doi:10.5194/nhess-12-2127-2012, 2012.