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Natural Hazards and Earth System Sciences
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Discussions

# *Interactive comment on* "Agricultural losses related to frost events: use of the 850 hPa level temperature as an explanatory variable of the damage cost" *by* K. Papagiannaki et al.

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ANSWERS TO THE REVIEWERS' COMMENTS We would like to sincerely thank the two reviewers for their constructive comments that helped us to significantly improve the presentation and the overall argumentation and quality of our paper. Following all their comments and suggestions we proceeded to a thorough revision of the article. In more detail, the following changes have been made in accordance with the respective comments of the reviewers: Reviewer 1 Specific comments 1. 'In Section 1 (Introduction), page 2, line 12: "Weather is definitely the major risk in agriculture" is not an appropriate phrase and should be a changed to a something like "Extreme weather or



adverse weather conditions…".' The specific sentence has been rephrased according to the suggestion. 2. 'In Section 2 (Data and methodological issues), page 6, line 6: The term "daily announcement" should be more clarified i.e. includes the totaled insurance damage payments of the day? or all the individuals insurance records corresponding to each particular day?' Data provided by GAIO actually consist of the total crop damage announcements and the respective monetary compensations by municipality and meteorological risk, aggregated at daily level for the period 1999 to 2011. To make it clear, we rephrased according to the suggestion. Relevant clarifications have been made where needed in the rest of the text. 3. 'In Section 2 (Data and methodological issues), page 7, line 2: The damage insurance level payments do not represent the total 100% of the crop damage. There are some "legitimate deductions" of the level of 15%. Also, damage level less than 20% is not paid and thus in not included in the insurance damage payments. This information should be included in this paragraph and if elsewhere needed in the text explaining that economic amount data examined do not represent the complete (100%) crop damage.' We rephrased according to the suggestion. Relevant clarifications have been made where needed in the rest of the text. 4. 'In Section 2 (Data and methodological issues), page 7, line 10: As the text in the following is everywhere referred to 850 hPa minimum temperature, it should be specified here if the minimum daily temperature value of the 6-hour time intervals was used in this analysis.' The minimum daily T850 value of the 6-hour time intervals was used in the present analysis. This information has been also inserted into the text following the relevant suggestion. 5. 'In Section 3 (Methods) page 9, line 5: The number of observations (N) as it referred to "daily damage announcements" should be clarified if they are total daily damage or individual damage records of any particular day.' The number of observations (N) refers to the amount of damaging frost events that occurred in each region at daily level between 1999 and 2009, and derives as the aggregation of the respective total daily damage records at prefecture level. This information has been inserted into the text following the relevant suggestion. 6. 'In Section 4 (Discussion), page 14, lines 4-5: Given the smallest number of damage announcements and the smallest damage cost occurring in Autumn in comparison to other seasons, it is an interesting result that the probability of damage to occur is highest for Autumn to both North and South areas (Table 5). Is it a result primary related to temperatures or to frost vulnerability of exposed crop types in Autumn? any comment or explanation is welcome here.' Indeed, autumn has been found with the highest probabilities for a cost to occur when tmin is low (tmin_3 level). Also, results of the regression analysis are not statistically significant in what concerns the difference in the effects of spring and autumn on the damage cost attributed to frost events in the south region examined. A more careful inspection of background data, following the reviewer's suggestions, came up with explanatory comments that are believed to clarify the analyses outcomes. More specifically, in the period 1999-2009, spring and autumn in the south region exhibited approximately the same rate of financial losses due to crop damages during frost events (41 and 45 million euros for spring and autumn frost events, respectively), which partly explains the regression analysis outcomes. Regarding the high probabilities for any cost to occur in the low tmin level, autumn involves the greatest risk in both regions compared to the other seasons. This outcome depends of course on the selected tmin thresholds and the frequency of tmin_3 observations recorded in autumn. It is interesting to observe in the number of days that correspond to tmin_3 level, for the period 1999-2009, and associate or not with crop damages (new Figure 5). The number of days with tmin_3 observations is very low during autumn in both regions and almost all of them (8 out of 9 days in the north and 6 out 7 days in the south) associate with the occurrence of crop damages. This analogy is obviously responsible for the high probability of any cost to occur in the low tmin level. Accordingly, the respective proportions for spring and winter lead to lower or much lower probabilities for crop damages. It should be noticed that the entire Section 4 (Discussion) has been thoroughly revised, following the suggestions of both reviewers and especially due to the addition of the validation process of the logistic model on a 2-year validation sample. 7. 'In Section 5 (Concluding remarks), page 15, line 11-13: Following the above, the conclusion here should be also completed with some small comment



explaining the statistical high risk of Autumn frost damage costs, given the smallest overall frost damage events and cost exhibited in Autumn.' Concluding remarks have been revised accordingly. More comments, explaining analytically the statistical high risk of autumn, are included in Section 4 (Discussion). Technical corrections 1. 'In Section 4 (Discussion), page 14, lines 8, 12: Where it is referred temperature units "C", should be corrected to "oC".' Corrections have been made according to the suggestions. 2. 'Same corrections as above, page 14, lines 23, 25.' Corrections have been made according to the suggestions. 3. 'In Figure 2, the y axis scaling might be better readable if would be changed to million Euros, instead of Euros.' Corrections have been made according to the suggestions.

Reviewer 2 General comments 'The paper focuses on analysing the risk of frost events and their relationship with agricultural losses, studying the relationship between the daily minimum temperature at the low levels of the atmosphere and more precisely at the pressure level of 850 hPa, and monetary compensations for crop damages attributed to frost. I would like to know why the authors have not used the surface temperature; topographic factors and variations in the boundary layer can mean that the data are not representative. The authors should include a more complete logistical model, in which the explained variance increases, validated using an independent sample. I would therefore recommend that a series of changes be made to the paper.' The reviewer's concern regarding the variables explored and the magnitude of the explained variance is acknowledged. We hope that the following reply to the comments will provide appropriate explanation for the selection of the specific variables (T850 and seasonality). According to the past studies, the extent of freezing is determined by minimum temperature, crop species and the state of development of plants. As mentioned in the introduction, freezing temperatures in combination with plants growth timing determine frost damage (Eccel et al., 2009; Rigby and Porporato, 2008; Rodrigo, 2000). Temperature at the pressure level of 850 hPa has the advantage of being a more consistent indicator of forthcoming weather conditions compared to the near-surface temperature, which is more influenced by conditions such as cloudiness and phenomena related with local topographical features. Also, significant advantage is that 850 hPa is a standard level of model analysis fields and, thus, there is a high availability of gridded data time-series covering the entire period under examination. Thus, if T850 is proved to be a parameter that can be directly linked to the development and magnitude of frost damaging events, its highly reliable forecast can be used for the development of practical and useful warning tools. Crop sensitivity of course is strongly affected by ground local conditions, while the relation with temperature in higher altitudes is certainly weaker. However, due to the fact that near-surface temperature represents the very local conditions and accounts for the very local agricultural damages, a very dense and long-time operating network of meteorological stations is required to obtain consistent time-series observations. The existing meteorological network in Greece is currently inadequate for such an analysis. In what concerns the plants growth stage, it is partly captured by the inclusion of seasonality in our analysis, since the phenology of plants is closely related with the yearly cycle of plants growth. With regards to the species of crops, we utilized available information concerning the crop species cultivated in the two regions under examination. According to the official statistics, there have not occurred any significant changes in the areas cultivated or in crop production by species during the last decade, thus, overall the sensitivity of the examined regions to frost events, as measured by the sensitivity of the specific crop species to the occurrence of low temperatures, has not changed. Data on the type of crop species damaged by the examined frost events were not available and thus have not been taken into account in the statistical analyses. Other variables affecting frost risk may include precipitation (more details can be found in the context of the reviewer's 2nd specific comment) and snowfall. The inclusion of such variables could increase the variance explained by the model. Nevertheless, previous research consider these variables as having limited significance regarding the extent of plants injury compared to minimum temperature and growth stage. In addition, forecasting of such variables is complicated and highly uncertain. The reviewer's suggestion regarding the validation of the logistic model is considered significant for the improvement of the methodology.



Therefore, we proceeded to a thorough revision of the entire methodology taking into account the validation of the model that calculates the probability for any cost to occur in the various levels of minimum temperature (more details can be found in the context of the reviewer's 3nd specific comment). Specific comments 1. 'In Section 1 (Introduction): The authors refer to Climate Change and agricultural risks, but do not go on to analyse this in the paper. I think that the introduction could be significantly improved with a more meticulous line of argument.' Introduction has been enriched with the inclusion of some additional information about the relationship between climate change and weather related risks and with additional relevant references (Eccel et al., 2008; Ruiz-Ramos et al., 2011). The relation of weather extremes with frost risk in the context of our analysis has not been further discussed since the employed methodology does not go beyond the short-term analysis, while the annual data set is considered too short for observing trends on meteorological extremes. 2. 'In Section 2: The annual variability has not been analysed, probably because the annual data set is short. Is it possible that other meteorological factors such as precipitation may affect the sensitivity of crops, and that this causes changes in the damage caused by frost events? Should other meteorological fields be analysed that may include synergies, like precipitation?' Indeed, as it is mentioned in Section 2.2, the annual variability cannot be statistically assessed, considering the short time period examined. As far as the variables affecting crops sensitivity are concerned, precipitation may be one of them. However, to our knowledge, research has not yet produced valid results concerning the relation between precipitation and frost risk. According to the existing literature, frost risk is determined by the daily minimum temperature and the plants growth stage (Eccel et al., 2009; Rigby and Porporato, 2008; Rodrigo, 2000). The inclusion of seasonality in our analysis captures partly the effect of the growth stage, since the phenology of plants is closely related with the yearly cycle of plants growth. According to Rodrigo (2000), precipitation is not expected to be determinant, but rather indirectly related, in some species, to the hardiness of flower buds, by affecting their moisture content. The author, however, explains that the effect of the moisture content is not yet determined and may depend on the species or even other factors. Thus, inclusion of precipitation in the analysis could produce confusing results without the inclusion of other factors, such as crop species, especially since its effect on frost risk is questionable. Furthermore, precipitation data at such a temporal analysis (long time-series daily data) or spatial level (they should cover all local precipitation events, including solid precipitation which is seldom recorded, that occurred in the broad regions examined) do not exist. Such an analysis could be representative only for particularly small geographical areas, covered by local meteorological stations, which is though outside the current study's scope. Finally, the forecast of precipitation is highly uncertain compared to temperature and particularly T850, which is less influenced by cloudiness and local topography and morphology compared to the near-surface temperature and its forecast is highly reliable. 3. 'In Section 3 (Methods): I consider that the data treatment and conclusions are slightly lacking in content, and should be analysed in greater detail. I would like to see a contingency table in which the forecasting equations are applied to an independent sample. What are the FAR or POD of the logistic models?' Following this very important comment regarding the validation of the logistic model we proceeded to a substantial revision of the entire methodology, as well as of the discussion of results and conclusions. The methodological revision relates to the development of a validation process which entailed changes in the entire document. Specifically: 1. The 1999-2011 time-series data have been divided into 2 data sets, for the statistical analysis and the validation process respectively. Therefore, data of the 11-year period 1999-2009, were used to set the statistical models, while data of the 2-year period 2010-2011 constituted the validation sample used to evaluate the statistical outcomes. 2. Sections 3.1 (Measures) and 3.2 (Analyses) concern the statistical data set (1999-2009), while Section 3.3 (Validation) has been added to present the validation methodology (including the FAR score). 3. All tables in Section 3 (Methods), Section 4 (Discussion) Section 5 and (Conclusions) have been accordingly revised. References have been also updated (addition of Lopez et al. 2007) Note that regression results have not



changed significantly compared to the 1st submission's results that came up from the analyses of the period 1999-2011. Information on data treatment and discussion of results has also been revised and considerably improved. In what concerns the validation methodology, the results of the logistic regression analysis for the period 1999-2009, presented in section 3.2, have been used to establish the dichotomy of risk/no risk of frost events to occur. It was considered that probabilities under 50% correspond to events for which no cost is expected, while probabilities over 50% permit for a warning of frost damaging event (López et al., 2007). Based on this criterion and the results shown in Table 5, warning for possible crop damages is applicable only when T850 is forecasted to be lower than the tmin_3 threshold (low tmin level). This applies for both regions. However, as the events in the north were mainly low daily cost during the period 2010-2011, the validation was restricted in the south and for the events with daily cost exceeding 100,000 euros. During the validation period 16 events with cost exceeding 100,000 euros occurred in the south region, 6 out of which (accounting for 37%) of the cases were in the tmin_3 category. Although only for the 37% of the events there would have been issued a warning, these events accounted for the 79% of the total cost in the south for the examined period. The aforementioned percentages show that the tmin_3 threshold could be used at least as a threshold for issuing successful warnings for the high damaging events. Focusing again in the south region, the False Alarm Ratio (FAR), that represents the fraction of the predicted events that did not actually occur, has been calculated for the same validation period and equals 0.47. This FAR value is quite high, but it should be viewed under the light of the cost of mitigation strategies, which is a factor not considered in our study. 4. 'The graphic quality of the figures has to be improved to adapt them to the required level for a scientific article.' All figures have been revised according the suggestions. Two additional figures (fig. 5 and fig.6) have been included.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C693/2014/nhessd-2-C693-2014-

supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 865, 2014.



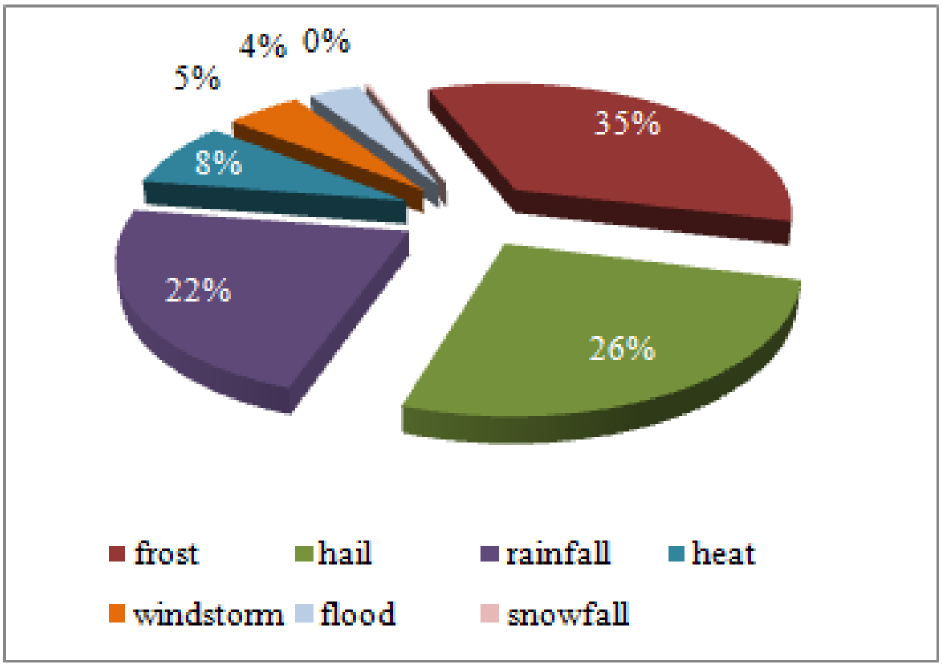


**Fig. 1.** Distribution of insured crop losses by meteorological phenomenon (1999-2011)

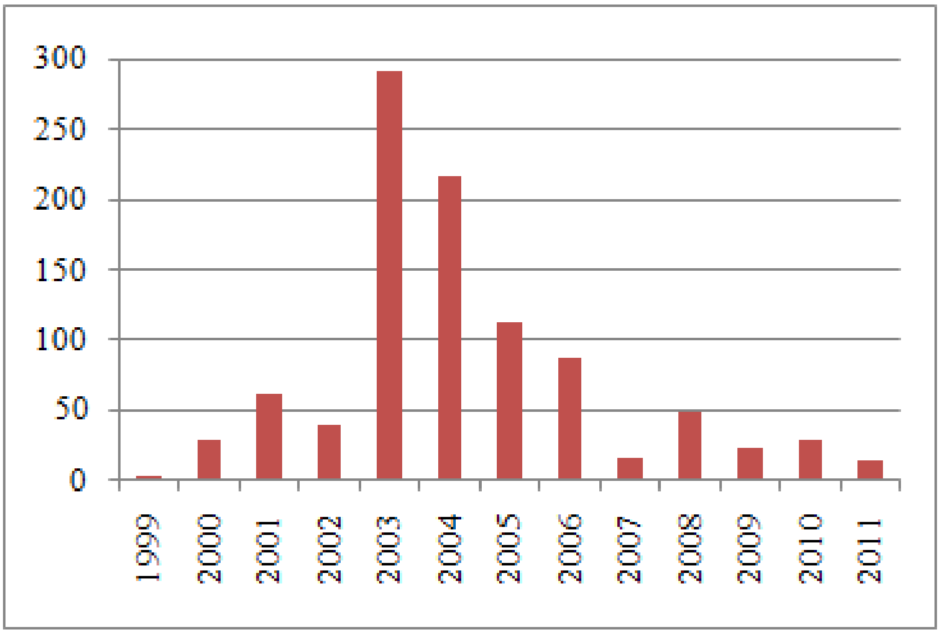


**Fig. 2.** Annual distribution of insured crop losses due to frost events, for the period 1999-2011 (in million euros)



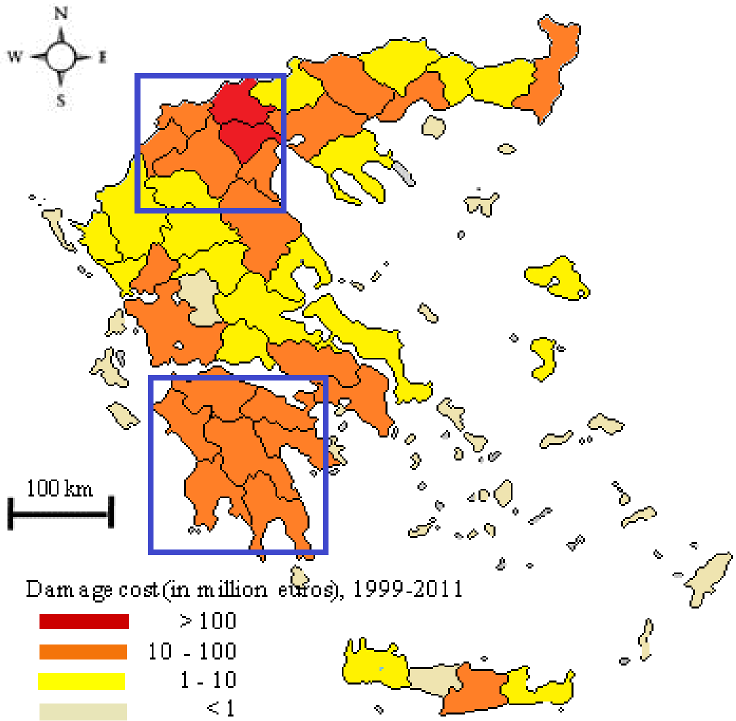


**Fig. 3.** Insured crop losses due to frost events by prefecture (1999-2011)

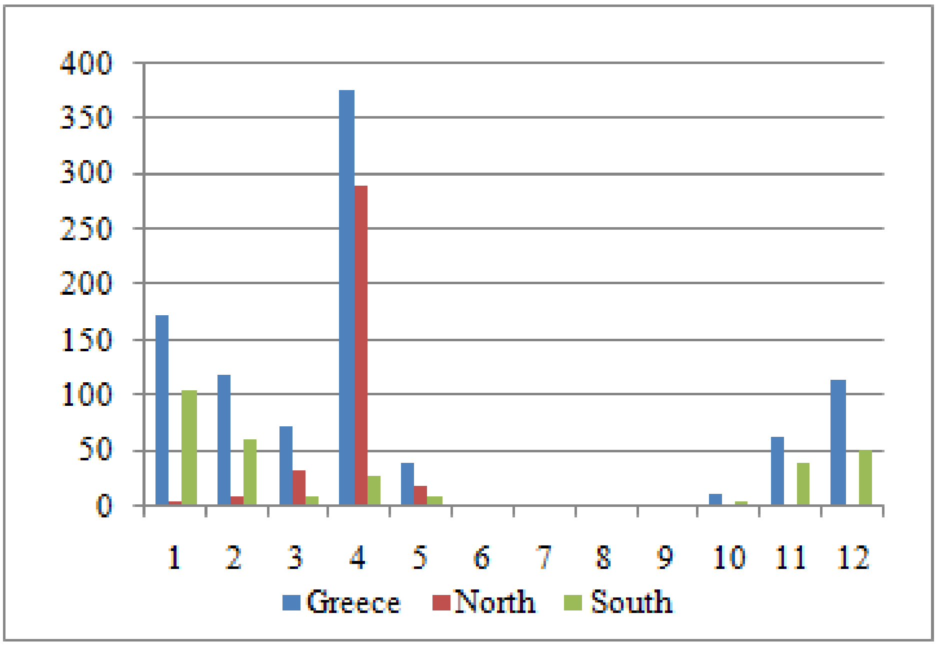


**Fig. 4.** Monthly distribution of insured crop losses due to frost events, for the period 1999-2011 (in million euros)



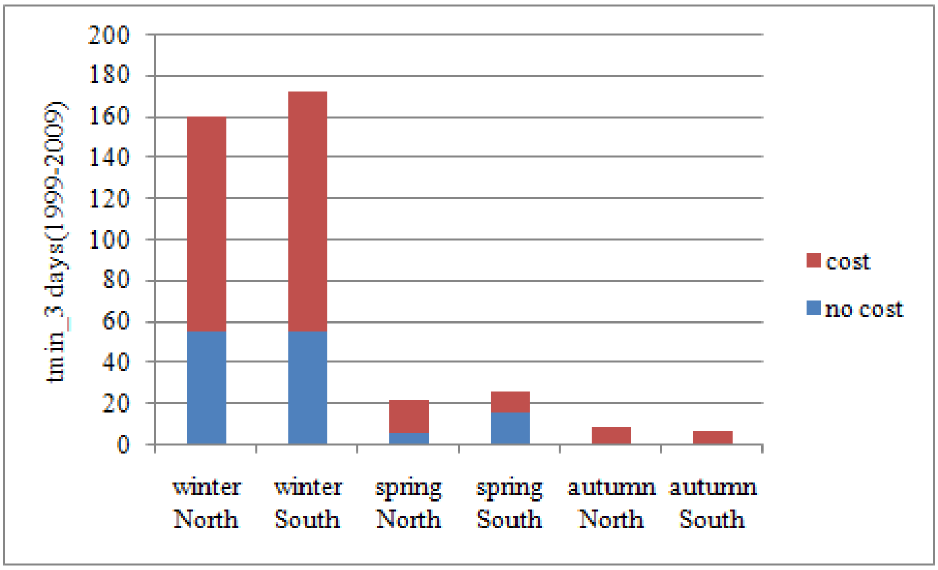


**Fig. 5.** Number of days with low tmin observations (tmin_3 level) by region, associated or not with crop damages (1999-2009)

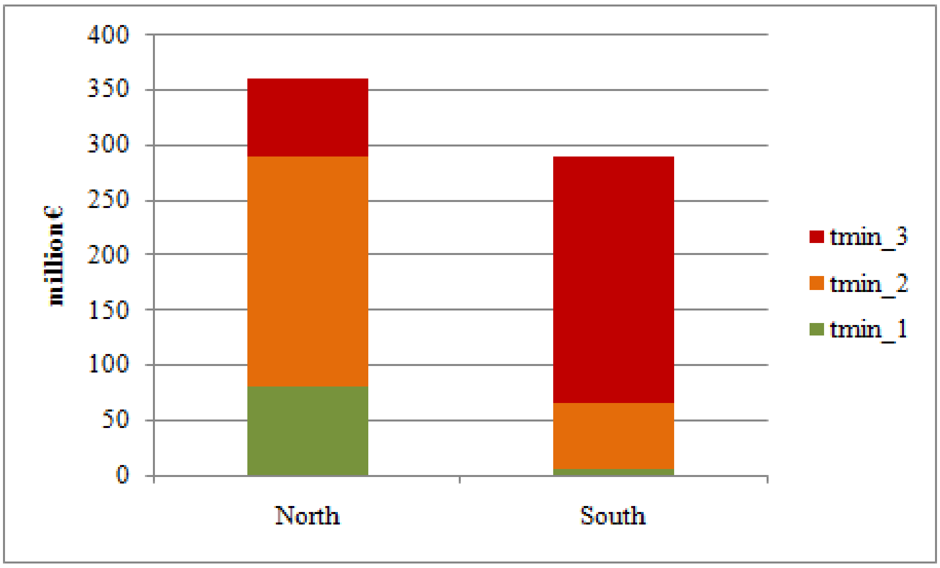


**Fig. 6.** Distribution of frost-related insured crop losses by tmin level (1999-2009)