Nuovo formato per la relazione scientifica dell'ultimo anno dei "Grandi progetti"

Responsabile scientifico: **Ilaria Pertot**

Acronimo: **ENVIROCHANGE**

Titolo: **Cambiamento globale e gestione sostenibile dell'agricoltura in un ambiente montano ad elevata antropizzazione/ Global change and sustainable management of agriculture in highly developed mountain environment**

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Lista partecipanti:

	Partecipanti	**Ruolo**	**Responsabile scientifico**
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SECTION 1: General overview of the project

Social, economic and ecological change is accelerating in highly developed (anthropised) Alpine areas such as Trentino, changes that combined with the effects of the predicted climate change threaten to alter crop quality, the distribution of existent species, enhance the invasions of exotic species, and cause changes in land use and cover that will reduce biodiversity.
Mountain regions are of local and global importance. They provide resources to half of humankind; including water, energy, food, food products and places for tourism. They are global centers of ecosystem complexity and biodiversity (in the broadest sense). Their steep slopes and sharp gradients make them highly diversified, but fragile ecosystems that are exploited for natural resources and used for recreation activities. In addition, globalization is contributing to the marginalization mountain communities and lessening the competitiveness of the farming sector. Nevertheless the agriculture continues to play a vital role in preserving the environment and landscape. The alpine agriculture has strengthened its multifunctional role as provider of a mix of private goods and public services, most of them are crucial for the tourism sector.
Currently, agriculture plays (directly and indirectly) a key role in Trentino's economy and in the preservation of its environmental capital. Predicted increases in temperature and decreases in precipitation due to climate change will add complexity and uncertainty to the agriculture system, threaten its sustainable management and have a negative impact on the environment, and hence on tourism. The impact of climate change on the melting of glaciers, reduced water availability, decreased biodiversity, and on plant stress and yield are well known, but climate change will also influence crop quality and dynamics of pest and diseases. Furthermore, competition from a global agriculture will further hamper the development of sustainable approaches to counteract global change. Scenarios and methods of analysis to cope with the multiple factors of global change are being developed and will be required to translate the current knowledge on climate change at the mega scale into local economic scenarios at the local level, a requirement for making sound policy decisions for environmental protection and sustainability.
The aims of the project were:
1. to assess the short-term impact (up to 25 years) of climatic change on agriculture at the regional level (Trentino) focusing on quality and pest management that are more likely to be influenced by climate change in the short term;
2. to assess the biophysical and socio-economic impacts of climate change on the region with special attention devoted to evaluating the economic impact on farmer profitability and on community welfare;
3. to evaluate autonomous adjustments and adaptation strategies made by farmers to global change;
4. to evaluate the economic, environmental and social sustainability of selected adaptation strategies.
The general objective was therefore to provide tools and information to understand vulnerability to climate change of the agriculture environment in Trentino and assess adaptation options suitable for Trentino's socio-economic conditions. Currently, most of the studies focused on the impact of climate change at a global level, without considering the regional levels, therefore the project will fill an important gap, not only providing specific information on Trentino's situation but also developing methodological approaches to be used in the future or in other similar areas. The project created important tools to forecast the potential impact of global changes on Trentino's territory and will strengthen agriculture with a sustainable development.
The final aim was to preserve and improve the quality of life of habitants, protecting environment and biodiversity for the future generations, but also to represent a model for sustainable development of mountain areas.
The expected results were:
1. The development of a GIS web-based tool (ENVIRO) to project the impact of climate change on the major crops and relevant pest/pathogens of Trentino;
2. A database including all relevant models and information on climatic requirements of pest and pathogens of relevant crops of Trentino and possible alternative crops;

3. Possible future scenarios of risk of the most relevant pest and pathogens of relevant crops of Trentino;
4. understanding the effect of climate change on some quality parameters as pollen viability, plant self-protection and ontogenic resistance and mycotoxins contamination;
5. understanding of effect of climate on some relevant tritrophic systems in the phyllosphere and soil;
6. understanding the effect of climate on some possible invasive species and emerging diseases
7. the identification of possible adaptation strategies to reduce the impact of pest/pathogens which may increase in the future (DSS, biocontrol agents, biochar);
8. a tool to evaluate the economic, environmental and social sustainability of selected adaptation strategies (DEXiPM);
9. understanding the grower and consumer behaviors in the view of climate change.

Describe possible changes in the state of the art, which happened during the project and had an impact on the project itself.

No major modifications to the original proposal were applied, but a general delay in starting the activity was common to all partners'. The delay was mainly due to the difficulties in recruiting personnel at the beginning of the project and the real starting of the project, which did not coincide with the beginning of the growing season for the crops used in the experiments. Several planned experiments were field experiments and since the beginning of the project was September 1, the field activity could start only in the next spring. A prolongation of one year was authorized by Provincia Autonoma di Trento. Other than this delay the activities were carried out as planned in the original Gannt chart.
Some technical modifications, based on the fact that new technologies become available after the project proposal submission, were applied. For example ETH proposed PCR-Select, which was a precious tool in the past to investigate differential expression of genes between two (or more) situation. Today this technology has been surpassed and other possibilities came to the marked. With the new generation sequencing (Illumina-Solexa), RNA-sequencing is becoming a widely used method, more reliable, cheaper and less time consuming than PCR-select, to accomplish differential gene expression analysis. Instead of qPCR, a new methodology was selected (LAMP) by ETH as it is of easier implementation and not needing expensive equipment, therefore better adapted to the proposed purpose. The trophic interaction between Trichoderma and Armillaria was studied by FEM with a new method based on using C13 stable isotope to monitor the uptake of nutrients during parasitation, and with a metatrascriptome approach. Biochar was included in the adaptation strategies by ARO because of it benefic role on the plant (induced resistance) and the advantage of being a moitigation strategy too.
Some changes have been introduced by FEM in the study of multitrophic, that were due to technical constrains, but did not impact the quality of the outputs.
Some changes in the approaches to assess socio-economic impacts of climate change (WP5) were also necessary. The recent applications of the Ricardian approach on European countries (Lang, 2007; Lippert et al., 2009; Fezzi and Bateman, 2010) published in peer reviewed journals suggested us to address the issue of Task 2 by using this approach. The identification of a new approach to elicit and estimate subjective probability distributions, the exchangeability method (EM) (Baillon, 2008), has lead us to employ it extensively in the analysis of both farmers and consumers risk perceptions. The choice of this approach make redundant the original idea to follow the 3 approaches (behavioural/attitudinal questions, interval hypothetical choices, investment choice) suggested by Fausti & Gillespie (2006, Austral. J. Agric. Resour. Econom., 50, 171-188). The development of a bio-economic simulation farm model, as planned in the original version of the project, resulted to be unfeasible. A careful review of the literature has indeed revealed the lack of crop models that could have been considered suitable for modeling the perennial crops grown in Trentino (e.g., orchard and vineyards). In addition, the limited time resources available to the project's partners for developing an ad hoc model pushed us to consider an alternative approach.

The paper by Couture, Reynaud, Dury and Bergez (2010) that was presented at the WCERE congress represented for us a stimulus to pursue our final approach. Similarly, the publication of a survey on climate change and adaptation strategies perceptions by experts at the European level (Olesen et al 2010) suggested the appropriateness to employ a survey instrument to test experts' perceptions at the provincial level. The development of a new flexible tool (Dexipm) starting from the DEXi decision support system (Bohanec, 2009) has provided us with a new tool to evaluate sustainability of adaptation strategies in a qualitative way. Given the lack of quantitative data on adaptation strategies, quantitative indicators as originally proposed were impossible to be built. A qualitative evaluation based on experts' judgment has proved to be a feasible and interesting approach to sustainability evaluation.

SECTION 2: Scientific report related to the fourth year

1. Summary of the activities

FBK

FBK consolidated the ENVIRO tool focusing on implementing the WPS technologies in the system architecture. Now web services can be run as usual from enviModel, but taking advantages of a much better system implementation and web interface. Moreover daily data about precipitation and temperature starting from 1967 up to 2011 have been interpolated obtaining daily average maximum, minimum and average temperature besides cumulated precipitation implemented into enviDb. Statistics to extract specific series to be used in enviMapper where calculated for precipitation as done already for temperature in year 3. New datasets have been loaded in enviDB.

ETH

This year was dedicated to the analysis of the transcriptome and therefore to the attempt to identify the genomic base of the ontogenic resistance. Comparison between the different conditions (young and old leaves, inoculated or not, and two time points 72/ 96 h) identified differentially expressed genes These genes were then characterized for their function by homology to *A. thaliana* and other plants' genes, particularly looking for gene involved in pathways already suspected of appertaining to ontogenic resistance in apple or other hosts, or to plant defense mechanisms in general. Six candidate genes putatively involved in the ontogenic resistance of apple were identified: a gene encoding for an "enhanced disease susceptibility protein" gene was found to be down-regulated in both not inoculated and inoculated old leaves at 96 hpi, while the other five genes (metallothionein3-like protein, lipoxygenase, lipid transfer protein, and two peroxidases) were found to be constitutively up-regulated in inoculated and not inoculated old leaves. This indicates that ontogenic resistance is the results of the corresponding up and down regulation of these genes, and that this preformed resistance occurs without pathogens contact.

A restricted number of samples Aspergilli was collected in Trentino to verify the current absence of OTA-producing Aspergilli, However main Focus was on establishing a fast method of identification of black Aspergilli carrying the genes for Ochratoxin A synthesis. The developed protocol uses the LAMP-technology and requires only a fast cultivation of fungi present on grape berries (24 h) and a transfer of mycelia to a pre-prepared micro tube. This is then incubated for 1 h at a constant temperature. Presence (or absence) of Fungi potentially producing the mycotoxin OTA are revealed through a change of color visible visually.

FEM

The implementation of the phenological models was achieved for grape phenology on 6 varieties and 2 trellis systems, for apple bloom, and for strawberry phenology. Regarding pests and diseases we implemented the different insect stages in the model of *Lobesia botrana* to get a more precise insight of the predictions. We also implemented the model of *Erwinia amylovora* infections on apple at bloom, powdery mildew on strawberry, risk of downy mildew infection. To estimate the impact on pesticide treatments we implemented an algorithm for the treatments on grapevien. Data for the implementation of three new models for pest/pathogens that will increase in the future have been generated (*D. suzukii. P. mali, R, necatrix*). The mechanism of induced resistance was fully elucidated and the effect of climate and variety was clarified. We also clarified the impact of climate on the selection of aggressive strains of downy mildew. The effect of temperature on apple and strawberry pollen viability was checked. We studied additional three systems. The first evaluated the effect of temperature and drought on the tritrophic interaction among plants, pathogens and biocontrol agent (*Bacillus amyloliquefaciens*), the second the effect of environment on the phyllosphere microorganisms on grape and a biocontrol agent (*Lysobacter capsici* PG4), the third on the impact of *Armillaria mellea* and *Trichoderma atroviride* on the soil microflora. We studied the effect of temperature (altitude), weeds and warming on soil microorganisms in vineyards, evaluated the effect of warming and the presence of weeds. We simulated two different climates on grapevine and evaluated the distribution of two pathogens (*Plasmopara viticola* and *Erysiphe necator*). Among the possible tools the trials on the last year concentrated on field

validation of a DSS for the treatment on grapevine, the implementation of the platform for the management of plant protection (case study on strawberry), the field trials on the protein extract SCNB2, *Ampelomyces quisqualis* ITA3 and its activator and *Lysbacter capsici.*

ARO

For modeling the epidemic of two diseases and their BCAs under different climates, the bacterium B52 and the yeast Y153, each had higher population level in the higher as compared with lower temperature. The presence of both pathogens on the tomato plants allowed even a significantly 5-10 times higher population of the BCAs. Both climate change and the pathogens affected the populations. Two diseases, powdery mildew (PM) and late blight (LB), spread with time over a population of tomato plants and reached higher rate of spread under conditions of higher temperatures which simulated a possible climate change. The two diseases influence each other in presence of BCAs. It is expected that more PM and LB will prevail if climate will be warmer and the disease of warm climate (PM) will be superior to the disease of relative colder climate in quantity and distribution.

Crop protection adaptation tools included the BCA *T. harzianum* T39, the reference inducer benzothiadiazole (BTH) and biochar soil amendment, all working against foliar plant pathogens. The inducers were found as effective adaptation tools being able to suppress diseases on canopy of tomato and strawberry plants. Furthermore, whole plants transcriptional changes related to salicylic acid and ethylene were induced by BTH. Drenching T39 caused jasmonic acid related changes. Interaction between B. cinerea infection and control agents treatment in detached leaves revealed that drenching with T39 suspensions as well as with biochar induces systemic resistance against *B. cinerea* and priming of salicylic acid and ethylene-related gene expression.

Biochar, a solid product of biomass pyrolysis is a novel control agent inducing systemic resistance to foliar pathogens in various plants when amended into the soil. We developed this innovative crop protection adaptation tools, effective against pathogens. These include a BCA *T. harzianum* T39 and biochar. Both are effective against foliar diseases and in the present research we showed mechanisms of induced resistance. Genes operated in tomato were characterized and a priming effect was found. Earlier we reported regarding strawberry and this time we report an alternative crop. Biochar was found not only as a mitigation tool but also as an adaptation tool that assists plants with growth and controls diseases.

Deliverables include the model of spread of two diseases under climate change conditions and with BCAs and adaptation and mitigation tools that can be used in various pathosystems.

UNITN

New and more robust estimations of the Ricardian approach on 126 irrigated farms using climate normals (average temperature and precipitation 1961-1990) show that Trentino agriculture will experience negative effects as a consequence of an expected increase in temperature (+1.4°C) and decrease in precipitation (-6%). The reduction in annual net revenues ranges from a minimum of 78.33 €/ha to a maximum of 750.29 €/ha but the overall impact could be underestimated as the more adverse effects on non-irrigated farms are not taken into account. The hill-shaped relationship between farm profitability and average temperature and precipitation is confirmed also by using annual weather data (2003-2007). This analysis highlights the variables that influence current farm profitability in a significant manner. Among others, net revenue per hectare depend heavily also on farmer's age and on the values of variables connected with farmer's strategies such as specialization and quality certification and insurance subscription. From the surveys with farmers, evidence emerged that the majority of interviewed farmers not only are familiar with the perils due to climate change in general but also display quantitatively detectable perceptions of future hazard to their farming operation that are directly or indirectly related to climate change. This is an encouraging result because shows that farmers are aware of climate change related risks, a necessary condition for farmers to be willing to engage in adaptation strategies. Another important result that emerged from the work we conducted with farmers is the statistical significant relationship between risk perceptions and risk attitudes. Specifically, we find that farmers who are more (less) risk averse tend to perceive greater (smaller) probabilities of farm losses occurring. This result has important implications also for future theoretical studies. Indeed this relationship has been neglected in

existing studies, which are therefore subject to be biased. The experimental component of our study has revealed the importance of a realistic framework to be applied in gamble task experiments used to elicit. Specifically, from a methodological point of view we find that only a gamble task defined in terms of farm income is good in predicting farmers insurance purchase decisions. Also in this context, our work has provided a contribution to the literature on risk preference elicitation whose implications reach beyond the concrete application and farmer sample that we analyzed. Finally, our work provides a contribution in terms of econometric analysis. We are the first to use subjective probabilities to estimate the risk aversion coefficient in a discrete choice context. From the analysis of the data collected with a survey carried out on 14 experts belonging to the viticulture advisory service of FEM emerged that climate change is not perceived to impact a great deal on the Trentino agriculture and most experts do not expect big changes in adaptation practices. The analysis of sustainability of four adaptation strategies (variety switch, crop switch, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones) highlights only small difference in terms of sustainability among the selected adaptation strategies in the specific case study. More interestingly the DexIPM tool emerges as a flexible and suitable tool for assessing sustainability of adaptation strategies at the farm level. From the Choice Experiment on 797 respondents from the Province of Trento dwellers emerge to expect an increase in the number of apples containing pesticide residues (75 out of 100 in 2030 with a 50% change). The willingness to support pay for R&D programs for developing innovative methods to control the spread of new apples diseases due to climate change depends on the number of apples containing pesticide residues, on risk attitude, time preferences, net annual income, being an apple consumer or producer, and consumer association membership. The marginal WTP for a reduction from 75 to 15 apples containing pesticides in around 1,2 euro per taxpayer per year. From a methodological point of view evidence emerges the risk information provided in the Status Quo alternative strongly affects choice behavior and the WTP for reducing the risk of pesticide residues.

Highlight possible deviations from the original project proposal

FBK

No major modification

ETH

As the current standard is whole transcriptome sequencing we opted for a more in depth analysis of the total transcriptome and instead of using three different cultivars three full repetitions of the same cultivar Golden Delicious were made, resulting in a statistical high quality of the analysis. Task 5 in the original project we prospected to use the RT-PCR technology for developing a rapid identification test for OTA producing fungi. Scientific advancement allowed to develop the LAMP test for this purpose witch needs a much cheaper equipment (thermal block instead of a cycler and no electrophoresis) and no special knowledge with a clearly lower total cost per sample.

FEM

We could not implement the biocontrol index because of the high variability on grapevine compared to potatoes where it was first developed. Therefore we change approach and studied the impact of the environment on natural microflora and biocontrol, with a metagenome approach.

ARO

We established a system of biochar soil amendment and its effect on plants growth and plants resistance to pathogens. We followed the mechanism by which biochar affects plant health in order to further development its potential. The biochar arises as a new tool, not only for mitigation of climate change, but also as an adaptation tool. The elaborated research on the subject was added to the research part of the project because of its significant contribution to the theme of EnviroChange.

UNITN

As already described Task2 of activity 5 was addressed by applying the Ricardian approach. The exchangeability method (EM) was employed extensively in the analysis of both farmers and consumers risk perceptions. We had to drop the idea to build bio-economic simulation farm model and data collection for addressing task 3 and 4 were integrated into a two round farmers survey.

We carried out a small survey on experts which was nor foreseen and the development of DexIPM allowed us to overcome the difficulty to gather a huge amount of data for sustainability assessment of adaptation strategies. The original task of evaluating “the social acceptability of some adaptation strategies” had to be redefined according to the evidence that laypeople mostly concern about their health and the effects of adaptation strategies on the use of pesticides. We had therefore to shift our focus from general adaptation strategies to the crop protection strategies and the R&D which is necessary to face future pest developments.

2. Report on the activities of the fourth year/Rapporto sulle attività svolte nel periodo di riferimento

At the end of the third year the following project activities were carried out:

WP 1 Assessing the effects of climate change in Trentino agro-ecosystems: the ENVIRO tool

ENVIRO system was improved. Database was enriched, validated and technologically optimized-Web interface was developed with the enviGrid.

Regarding the construction of weather scenarios under global warming and custom conditions in the third year the following activities were carried out: to conclude the missing precipitation data reconstruction; include an algorithm for the correction of snowfall underestimation; production of a database of the homogenized daily series of temperature and precipitation; building a downscaling procedure, using climatic projections for a selected downscaled number of sites (10) to produce downscaled seasonal projections for the maximum number of sites, building a multi-site weather generator to produce daily series from seasonal averages and projections; hourly interpolation of temperature series (both measured and projected); and feasibility study for the estimation of relative humidity series from temperature and precipitation data, for pathogen modeling purposes.

Models were implemented in the ENVIROCHANGE WPS server (*Lobesia Botrana*, Powdery Mildew Index, MaryBlight, Chardonnay Phenology. FBK did the code generalization and server configurations for Web Processing Services (WPS) and the entire WPS on Cloud infrastructure was implemented. We had some exploratory researches as the use of GIS – and the integration of pre-existing models, climate change data and axillary database for climate change impacts studies, risk mapping and reporting statistics.

FBK developed enviMapper tools for decision makers and enviModel tools for researchers. We developed the visualization of models in the past and for future projections and we did supplementary review on works dealing with Climate Change applications: Climate change impacts and climate change impacts on agriculture.

WP2 Assessment of biophysical impacts of climate change on quality and production of crops of Trentino

The direct effect of climate change on quality and production indices, the identification of algorithms predicting phenological stages, climate-dependent quality and production indices for crops of interest that currently existing in Trentino (apple, grapevine, strawberries, and other berries and some horticultural crops) were completed (ARO/FEM).

Regarding the description of the onset of ontogenic resistance in apple leaves in relation to temperature ETH validated the method and the ontogenic resistance was studied at different temperatures and the gene set genes responsible for ontogenic resistance was found.

Trichoderma harzianum T39-induced resistance against *Plasmopara viticola* was characterized and the physiological responses were studied in heat and drought stressed grapevine plants. Trials to characterized the physiological effect of plant genotype on induced resistance were carried out and we did the PR-genes analysis and real time PCR validation in experiment infection with *Plasmopara viticola* (FEM).

ETH developed a rapid, easy to implement, test for presence of Ochratoxin producing Aspergilli and executed the third sampling for the presence of OTA producing Aspergilli in Trentino.

WP3 Assessment of biophysical impacts of climate change at multitrophic level on crops

FEM identified the spatial and temporal dynamics of pest/pathogens of Trentino's major existing crops, their antagonists and their correlation with weather parameters, obtained a database (DB) of the existing information on pest and pathogens (P/P) of major Trentino's crops (gnoseological starting point of the project) and ARO identified spatial and temporal dynamics of pest/pathogens of selected alternative crops and their antagonists and their correlation with weather parameters. A literature search of existing models was carried out.

FEM developed phenological models of different varieties of grapevine with susceptible stages for P/P, specifically: production, validation and/or calibration of existing models on P/P to be used in ENVIRO (FEM); projections: assessment of climate change impact on the interaction between P/P and the host plant for Trentino; scripts for more friendly visualization of the information in ENVIRO WEB-GIS and retrieved data on European grapevine moth (*Lobesia botrana*) flights and powdery mildew (*Erysiphe necator*) damage from Trentino and neighboring regions

Relations among Plant/pathogen/antagonists in the phyllosphere were studied and specifically: the effect of climate on the interaction of plant, pathogens and antagonists: influence of environmental stress on lipopeptide production and biocontrol capability of Bacillus subtilis - continuation (FEM); the effect of climate on downy mildew populations (setting the method to test genotypes) (FEM) and the effect of climate conditions on plant diseases and their biocontrol agents (ARO).

Relations among plant/pathogen/antagonists in the soil were studied and specifically: samples for the study of the effect of temperature on soil microbial population in vineyard soil were collected and processed (FEM); the experimental set up for gene expression profiling by massively parallel sequencing induced by Armillaria mellea and Trichoderma atroviride in an artificial multitrophic system was finalized; the method to study of trophic interactions between a plant pathogen and two different antagonistic microorganisms using a 13C-labeled compound and isotope ratio mass spectrometry was set up.

WP 4 Development of highly innovative tools for adaptation in crop management (i.e. expert systems, decision support systems, biocontrol agents, vibration based mating disruption, etc.) to the forecasted/expected changes.

The activities so far focused on the non-chemical control agents of strawberry powdery mildew, the preparation of the experiment set up to study Trichoderma harzianum T39 and acibenzolar-S-methyl induce disease resistance in tomato and strawberry, the characterization of biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media, the impact of biochar application to soil on the root-associated bacterial community structure in fully developed greenhouse pepper plants and the impact on development and productivity of pepper and tomato grown in fertigated soilless media and the impact of biochar application to soil on the root-associated bacterial community structure in fully developed greenhouse pepper plants (ARO). Induced resistance mechanism was studied in strawberry and tomato plants.

We implement a working prototype of a platform for identification of plant pest and pathogens (identificator) (FEM-ARO in collaboration with Haifa University) and a working prototype of a platform for managing adaptation tools and pesticide treatments on strawberries (Monberry) (FEM-ARO in collaboration with Haifa University).

WP5 Assessment socio-economic impacts of the most probable scenarios and evaluation of adaptation strategies that can be taken

The dataset containing information about the 312 farms growing apple and grapes which are included in the Farm Accountancy Data Network in period 2003-2007 is completed and verified. It contains farms, soil an farmers characteristics, farm spatial coordinates and interpolated climate variables.

Investigation on the relationship between farm income and climate related variables using the dataset assembled in T1 has been performed according to the Ricardian approach. Estimation results have been presented in international conferences receiving feedbacks on how to improve the models.

Data necessary to investigate apple and wine growers' risk perception of climate change, pest and hail risk and risk attitude have been collected through a survey and organized in spreadsheet with 196 complete and usable observations (75 winegrowers and 121 apple farmers).

Data necessary to model farmers decision of buying insurance have been collected through a two round survey. Apple farmers (317 subjects) completed two stated preference experiments, provided information regarding their actual insurance decisions and many other information on farm's and

farmer’s characteristics. A new dataset containing 317 complete and usable observations concerning about 100 variables is arranged in an Excel spreadsheet.
The tool to use for sustainability assessment has been identified in the DexIPM software.
The CE on 288 apple consumers has revealed that consumers are currently willing to pay only for organic production method but dislike IPM or IPM using biological control agents extensively. Consumers are willing to pay for mitigation practices that reduce the greenhouse gas emissions. The suitability of the exchangeability method in eliciting the risk perception in general and risk perception of pesticide residues has been tested in two experiments: one carried out in Texas and the second one in Trento. Focus groups with consumers has highlighted that, for what concerns the effects of climate change on agriculture, laypeople are worried about the effects of adaptation strategies on the use of pesticides. We decided to focus on people’s preferences for diverse adaptation strategies that apple producers might use to fight the Fire Blight. These strategies are chemical control, biological control, and the usage of resistant cultivars and they have an effect on the number of apple containing pesticide residue in 2030 and the related probability.

List the WP and specify the role of participants

WP 1 Assessing the effects of climate change in Trentino agro-ecosystems: the ENVIRO tool
FBK Coordinated the development of the ENVIRO tool and of its modules:
enviDB, enviGRID, enviModel, EnviMApper.
FEM provided climate and biological data and models.
WP2 Assessment of biophysical impacts of climate change on quality and production of crops of Trentino
ETH answerdd the questions: Will under a similar rain fall pattern lead to changes in apple scab severity on the Trentino orchards? Will a prospected temperature increase lead in the Trentino vineyards to mycotoxin contamination and can a fast diagnostic tool employable in any major cellar be developed.
FEM characterized induced resistance on grape and impact of climate on the mechanism; the effect of climate on quality parameters including pollen viability.
WP3 Assessment of biophysical impacts of climate change at multitrophic level on crops
ARO modeled the epidemic of two diseases and their biocontrol agents under different climate, microbial populations of BCAs, characterization of the spread of two diseases in a population of tomato plants.
FEM characterized the impact of climate on BCAs, pathogens, and tritrophic interactions in the phyllosphere and soil.
WP4 Development of highly innovative tools for adaptation in crop management (i.e. expert systems, decision support systems, biocontrol agents, vibration based mating disruption, etc) to the forecasted/expected changes.
ARO studied otential adaptation and mitigation - induced systemic resistance against gray mold in tomato by benzothiadiazole and *T. harzianum* T39; Induced systemic resistance in tomato by biochar soil amendment.
FEM studied decision support systems and biopesticides alternatives to chemicals as adaptation tools
WP5 Assessment socio-economic impacts of the most probable scenarios and evaluation of adaptation strategies that can be taken
UNITN assessed the impact of the scenarios

Activity 1 Assessing the effects of climate change in Trentino agro-ecosystems: the ENVIRO tool

Objectives

Task 1 Development of an integrated EM/GIS analysis tool for Trentino's major agricultural pests (ENVIRO). The foreseen modification of Trentino's agro-ecosystems after climate change will be precisely investigated by developing an integrated EM/GIS analysis tool for Trentino's major agricultural pests. This analytical tool will display the effect of environmental variables on P/P development and spatial distribution in the major agricultural systems. It is needed to develop a library style implementation which covers the current knowledge of agro-ecosystems but can be easily extended to other systems and updated with new knowledge. This library shall cover disease patterns at different spatial and temporal scales.

Task 2 Construction of weather scenarios under global warming and custom conditions. Since future dynamics of the expected climatic change at a regional level are still unpredictable and uncertain, a set of possible scenarios under global warming and custom conditions will be set up to run the EM/GIS tool.

Task 3 Integration of GIS, weather and field data and remote sensing data. Various data sources are needed to run the models: besides classical GIS, weather and field (quality, P/P, farm income) data, remote sensing data will be integrated.

Task 4 Prediction of P/P spatial patterns and fruit quality loss under climate change scenarios

Visualization on Trentino maps of ecological niches suited for hosting P/P and of areas where fruit quality is impaired. This objective is achieved by running ecological models under the GIS and RS environment under different weather scenarios and by displaying spatial information on geographical maps. Those maps will indicate areas with potential P/P establishment or immigration, fruit quality variation and the economic loss. Temporal pattern extraction from the meteorological database will permit the development of short-termed and long-termed adaptation strategies and evaluate their impact on the agricultural system.

Role of participants

FBK will implement the ENVIRO an integrated weather driven physiologically based Ecosystem Modeling (EM) and Geographic Information Systems (GIS) for Trentino's major agricultural pests (ENVIRO). Database set up and management, real-time weather data collection, weather scenario set up and management, remote sensing, GIS-, EM modeling and execution.

FEM will deal with catalog and EMs and the Integration (from Activity 2, 3, and 5) of quality and production indices, P/P life cycle phases, environmental parameter promoting development, selection of economically important P/P present or potentially immigrating to Trentino, life cycle investigation of P/P scarcely reported in literature.

Activities

Task 1

FBK worked consolidating the ENVIRO tool and its modules. A specific Django module was developed to frame the web processing services developed together with FEM scientists in ENVIRO. Today researchers using enviModel can map the dynamics of *Lobesia botrana*, Powdery Mildew Grape, Phenology Chardonnay, Phenology merlot (including photoperiodic input), *Botrytis Cinerea* Grape, Huglin bioclimatic index, Downy Mildew, Mary Blight, *Lobesia Botrana*, Powdery Mildew Index, MaryBlight, Chardonnay Phenology on past climate data and on future climate scenarios. A complete, 1m resolution digital terrain model and its derivatives (slope, aspect, hillshade) covering the whole area of the province of Trento have also been implemented into enviDB and is accessible through enviMapper and enviModel. Meatadata that describe how climate models and EM models are implemented and processed are available on the web interface and can be visualized to enable users to make the process reproducible. FBK implemented as a WPS a simulation process of the a warning model and a decision-making procedure to optimize the use of copper on wine against downy mildew. This system is based on treating vines with a variable rate of

copper when there is an immediate risk of infection and the vegetation is not sufficiently protected by previous treatments.

Task 2

The activities are shortly listed:

- The weather generator RMAWGEN was improved and completed to work at best for the generation of precipitation fields;
- the hourly interpolation of temperature was checked and fixed for the generation of hourly series from the daily ones;
- the downscaling of climatic projections of precipitation was done;
- the "sub-downscaling" of temperature and precipitation was done;
- the procedures for the generation of atmospheric humidity were resumed and applied to the climate projections, to produce future scenarios.

A short description is given for each item.

The w.g. "RMAWGEN" was set up and published as an open-source R library (Cordano and Eccel, 2011). This multi-site working is mandatory when the series are required for the eventual spatial interpolation of results.

The algorithm for hourly interpolation was fixed. This is important for the generation of mean daily temperatures from min and max values and for the generation of relative humidity fields, which requires hourly values.

The statistical downscaling of precipitation was carried out in collaboration with ARPA Emilia – Romagna, who applied a Canonical Correlation Analysis procedure.

The "sub-downscaling" algorithm is a "partial-least-square regression" which extends downscaling of projections for a large number of sites, having as input the seasonal projections from the statistical downscaling (see more details on the "Report - year 3").

The projections for two sites (S. Michele and Cles) were generated and the simulation of atmospheric humidity was done by the algorithm developed on purpose. The aim is the application of a model for powdery mildew for grapevine, which takes into account the important role of leaf wetness.

Task 3

New climate data starting from 1967 up to 2011 were interpolated and stored in the database. Daily minimum, maximum and average temperature besides daily cumulated precipitation are now usable and visible from the enviMapper and the enviModel interface.

Task 4

The models that simulate the phenological stages, and life cycles of pathogens follow a rigorous series of steps to become part of the model library provided by the system. As first the model, written in R and already published on a scientific paper, is tested and validated for Trentino. The model is then translated into a process using standard OGC WPS and libraries for geospatial computing as GeoTools, Sexante and geo-processing library GRASS. The model once is become a WPS, is again tested matching the model output of the WPS together with the R model output set on a point validation dataset of Trentino. The process is the finally optimized, to decrease execution time.

Results

The ENVIROCHANGE WPS server was completed using two main WPS implementation Using enviMapper and enviModel it is now possible to map in Trentino, based on the available climate data and future climate change scenarios implemented in the enviDB, the potential diffusion of the following models: Lobesia botrana, Powdery Mildew Grape, Phenology Chardonnay, Phenology merlot (including photoperiodic input), Botrytis Cinerea Grape, Huglin bioclimatic index, Downy Mildew, Mary Blight.for Lobesia Botrana, Powdery Mildew Index, MaryBlight. of those areas where FEM 1000 ch

Deliverables

T4 D1 ENVIRO tool: Historical and global warming, temperature and precipitation scenarios included (FEM)

With reference to the list in the "Activity description":

Weather generator. The results are satisfying; this tools allows the generation of temperature and precipitation daily series from monthly means, maintaining the spatial correlation A paper was submitted to the J. Stat. Software (Cordano and Eccel, submitted).

An R library (Interpol.T) was published (Eccel and Cordano, 2012)

Seasonal predictions of precipitation depths and days were produced on 10 selected sites, for the periods 2021-2050 and 2071-2099.

This model was developed and applied for the future, but also for improving the climate characterization for the "control" period 1961-1990 (hindcast), where the instrumental series on the sites were often incomplete. The general issue of downscaling was the argument of a manuscript submitted to Climate Research (Eccel and Tomozeiu).

5The simulation of temperature and relative humidity were used to estimate the phenological timing of chardonnay at two selected sites and the powdery mildew infections. Work still ongoing, a paper is expected to be submitted by March / April.

T5 D3 Visualization of vulnerable host areas, ranges of expansion and climatic limits of P/P, under current and global warming scenarios (FBK/FEM)

The vulnerable areas can be now visualized on the maps.

T1-T3 D3 Two peer reviewed articles on ENVIRO and its applications

Gusberti, M., Patocchi, A., Gessler, C., and Broggini, G. A. L. (2012) Quantification of *Venturia inaequalis* growth in Malus × domestica with quantitative real-time polymerase chain reaction. Plant Dis. 96:1791-1797.

Caffarra A., Rinaldi M., Eccel E., Rossi V., Pertot I. (2012) Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. Agriculture, Ecosystems & Environment 148, 89-101,

Activity 2 Assessment of biophysical impacts of climate change on quality and production of crops of Trentino

Objectives

Task 1 Direct effect of climate change on quality and production indices.

Identification of algorithms predicting phenological stages, climate-dependent quality and production indices for crops of interest existing in Trentino (apple, grapevine, strawberries, and other berries and some horticultural crops).

Task 2 Genomics to phenology: effect of climate change (ontogenic resistance).

Description of the onset of ontogenic resistance in apple leaves in relation to temperature. Identification of the gene set which is expressed at the change from susceptibility to resistance and possibly identification of molecular mRNA based marker for this particular phase.

Task 3 Genomics to plant health: effect of climate change on plant self-protection (induced resistance).

Assessments of impact of temperature and drought (water stress) on induced resistance in grapevine. In fact in some host-pathogen systems resistance is reduced under drought conditions.

Task 4 Indirect effect of climate change on fruit quality. To evaluate if climate change has an effect on pollen performance (pollen tube kinetics and dynamics) considering the genotype-temperature interaction. Flowering is among the most vulnerable development stages to temperature fluctuation and the prevailing temperatures during bloom have an agronomic impact, which can result in poor fruit quality (size) or on fruit set. Evidences for differential interaction T-genotype in the progamic phase in fruit trees is described.

Task 5 Indirect effect of climate change on food quality (mycotoxins contamination).

To develop local scenario for risk of contamination of wine with mycotoxins based on the temperature driven model of the pathogen development and on the production of mycotoxins. To deliver a rapid and highly sensitive test for detecting the fungus and mycotoxin production in risk areas.

Task 6 Evaluation of agro-ecological quality: biodiversity and biocontrol under climate change.

Role of participants

T1: FEM, quality and production indices, and predicting algorithms (grapevine, apple, strawberries). FBK: algorithm development and validation of models.

T2: Genomics to phenology: effect of climate change on ontogenic resistance (genomic ETH, physiology FEM, bioinformatics FBK).

T3: Genomics to plant self protection, effect of climate change on induced resistance (FEM).

T4: Evaluation of pollen performances (FEM).

T5: Sample collection and preparation (FEM), genomics and RT-PCR development (ETH), analysis of results and model construction (FEM and ETH).

T6: FEM biological analysis, FBK: bioinformatics analysis.

Activity

Task 1

We implemented the phenological model of grapevine for 6 varieties on 2 trellis systems. The main phenological stages are bud break, 10 cm shoot, bloom, veraison, 8° Brix and harvest. We implemented the phenological model for apple bloom and for strawberry (bloom, veraison, harvest). A precise model which takes into consideration the different stages of *Lobesia botrana* was developed. We implemented a model to estimate the number of treatments on grapevine under different climatic scenarios. The model is based on the DSS Coptimizer and for downy mildew considers the risk of disease, the plant susceptibility the residue of the treatment, the number of new leaves and the meteorological conditions. The treatments against powdery mildew are calculated based on the residual effect of sulphur, the risk of the disease and the plant phenology.

Task 2

Ontogenic apple scab resistance is a horizontal resistance against the plant pathogen *V. inaequalis* and is expressed as decrease of disease symptoms and incidence with the ageing of the leaves. Several studies at biochemical level tried to unveil the nature of this resistance, however without any conclusive results. We decided therefore to investigate a putative genetic origin of this phenomenon by performing a full trascriptome sequencing and comparison of young (susceptible) and old (ontogenic resistant) leaves, infected or not with the pathogen. Two time points at 72 and 96 hours post inoculation were chosen for RNA sampling and sequencing. Comparison between the different conditions (young and old leaves, inoculated or not) should allow finding genes differentially expressed which may represent different induced plant defense reaction leading to ontogenic resistance or be the cause for a constitutive (not inoculated with the pathogen) shift toward resistance in old leaves. Differentially expressed genes were then characterized for their function by homology to *A. thaliana* and other plants' genes, particularly looking for gene involved in pathways already suspected of appertaining to ontogenic resistance in apple or other hosts, or to plant defense mechanisms in general. A lower number of genes differentially expressed between inoculated and non-inoculated leaves of the same age were found compared to those found between leaves of different age. In this work six candidate genes putatively involved in the ontogenic resistance of apple were identified: a gene encoding for an "enhanced disease susceptibility protein" gene was found to be down-regulated in both not inoculated and inoculated old leaves at 96 hpi, while the other five genes (metallothionein3-like protein, lipoxygenase, lipid transfer protein, and two peroxidases) were found to be constitutively up-regulated in inoculated and not inoculated old leaves. This indicates that ontogenic resistance is the results of the corresponding up and down regulation of these genes, and that this preformed resistance occurs without pathogens contact. The results of this work need to be validated by qPCR experiments using several apple genotypes, and gene expression levels correlated to protein levels by means of proteomic approach.

Task 3

We previously showed the ability of the beneficial microorganism *Trichoderma harzianum* T39 (T39) to induce grapevine resistance to downy mildew (*Plasmopara viticola*), although the molecular events associated with this process and their relevance under field condition have not yet been elucidated. During this year an integrated approach was used to study global transcriptional and proteomic changes associated with resistance induced by T39 in grapevine leaves. By next generation RNA sequencing (RNA-Seq) approach, more than 14.8 million paired-end reads were obtained for each treatment and 7024 grapevine genes resulted as differentially expressed during resistance activation. Moreover, 800 unique proteins were identified and quantified by high-throughput eight-plex iTRAQ protocol and 218 proteins resulted as significantly changed in abundance during T39-induced resistance. To evaluate the efficacy of the T39-induced resistance under non-optimal conditions and to study pathogen's infection dynamics of different *P. viticola* isolates we evaluated i) the T39-induced resistance in plants exposed to heat and drought stresses, ii) the T39-induced resistance in different grapevine cultivars and iii) the possible selection mechanisms of different *P. viticola* isolates under different climatic scenarios. We tested the effect of climate on competition among strains for *P. viticola* and dissected the competition mechanism by using a method based on microsatellite markers.

Task 4

We attempt to define if pollination of apples (main varieties and their pollinating varieties) and strawberries (main varieties) will be influenced by temperature increase. Closed flowers of two apple varieties (Golden delicious and Renetta) and a strawberry variety (Elsanta) were collected in the morning and let open at 20°C. Pollen was collected and placed on glass slides at 5, 10, 20 and 30°C. Pollen germination was viewed under a compound light microscope. Pollen was considered germinated when the pollen tube was one and a half to twice the length of the pollen granule. 5 and 30°C were detrimental for pollen viability, which was reduced by 50% in average.

Task 5

Aspergillus carbonarius and *A. niger* are responsible for ochratoxin A (OTA) contamination of grapes. Continuous monitoring of their presence in vineyards is part of the strategies to minimize

the occurrence of this mycotoxin in wines and other grape products. Aim of this work was the development of two assays based on the loop-mediated isothermal amplification (LAMP) of DNA for the quick and specific detection of OTA-producing *A. carbonarius* and *A. niger*. The two sets of primers were designed on the polyketide synthase (PKS) genes putatively involved in OTA biosynthesis in these two species. Hydroxy naphtol blue (HNB) was used as indirect method to indicate DNA amplification. Specificities of the reactions were tested using DNA from different black aspergilli isolated from grapes. The limit of detection of both reactions was comparable to that of a conventional PCR. The two LAMP assays were then used to identify *A. carbonarius* and OTA+ *A. niger* grown in pure cultures and in artificially inoculated grapes without a prior DNA extraction. The results presented here indicate that the LAMP reactions could be potentially applied in the screening programs of vineyards for the presence of OTA-producing black aspergilli.

Task 6

After several unsuccessful trials on standardizing a biocontrol index we adopted a differ approach on soil and phyllosphere. To evaluate the effect of temperature on soil microflora we analyzed microbial communities living in nine vineyards distributed over three altitudinal transects over two years. Fungal and bacterial community dynamics were explored using automated ribosomal intergenic spacer analysis (ARISA) and by determining bacterial cells and fungal colony-forming units (CFUs). Moreover extensive chemical and physical analyses of the soils were carried out. To further exploit the effect of soil temperature, we then carried out a one year microcosm experiment. Temperature is one of the most important factors affecting soil microbial communities and the recent worries about climate change stimulated the interest in a better understanding of its effect. Our aim was to assess the effect of temperature, isolating its effect from all the other parameters present on field. In particular we investigated the effect of seasonal soil temperature fluctuations and the effect of 2 °C soil warming in the range of the seasonal fluctuations. Furthermore we assessed the effect of stable temperatures without fluctuations (3 and 20°C). To fully characterize the vineyard environment we conducted a third experiment to understand the effect of weeds and of soil type on the bacterial and fungal community structure, to reflect on their role in this environment. Weeds are widespread plants in vineyards and are usually controlled because they compete for nutrients with vines. Through a greenhouse experiment where we used a combination of three different weeds (*Taraxacum officinalis, Trifolium repens* and *Poa trivialis*) and four different soils collected in vineyard, we aimed at characterising the bacterial and fungal communities of the bulk and rhizosphere soil and of the roots.

To assess the effect of climate on the phylloplane microflora and on its biocontrol ability in defense of the plant, we artificially inoculated a biocontrol agents (*Lysobacter capsici*) on grapevine under two different environmental conditions having an average difference in temperature of approximately 2°C over the season (Udine and S. Michele all'Adige) and controlled conditions in greenhouse in July 2012. Leaves were collected after 2 week, washed and DNA extracted and sequenced with NGS. The data indicate that the biocontrol agent is strongly influenced by environmental conditions, and the efficacy is higher when conditions are close to its optimum. The phyllophere bacteria are strongly influenced by the biocontrol agent under its optimal conditions.

Describe activities carried out by subcontractors

NGSequencing (FEM) was carried out by an external company.

Results

The models implemented in ENVIRO allow the visualization on the maps of the probable effect of climate change on the selected systems. Climate change will increase the number of generation of *L. botrana* however the last generation will develop when grapes are already harvested. Powdery mildew is supposed to increase in some areas, but decrease in others. The number of treatments will increase in some areas and decrease in others: Similar variability is also present in case of fire blight.

The complex transcriptional and proteomic reprogramming of T39-induced resistance included the direct activation of the microbial recognition machinery after T39 treatment and the enhanced

expression of defense-related processes after pathogen inoculation. T39-induced resistance partially inhibited some disease-related processes and specifically activated defense responses after pathogen inoculation. In particular, some defense processes known to be implicated in the reaction of resistant grapevines to downy mildew were partially activated by T39-induced resistance in the susceptible grapevine.

We could assess that co-inoculated *P. viticola* isolates competed for the infection of the host, although being equally infective when singularly inoculated regardless of the climatic conditions. Competition was not related to the origin of the isolate and we hypothesized that competitive selection was modulated by differences in the secretion of effector molecules, which explained the establishment of dominant genotypes over an epidemic season. We demonstrated that T39-induced resistance was found to be reduced in plants exposed to the combination of heat and drought stresses, moreover, variable levels of efficacy were observed in different grapevine cultivars. Modulation of the marker genes in the T39-induced resistance was partially attenuated in plants under heat and drought stress. The molecular mechanisms activated in response to the resistance inducer were different and complex among cultivars, indicating that specific receptors are probably involved in the regulation of the plant response. Different *P. viticola* genotypes reacted differently when co-existing on a unique substrate, indicating that plant-pathogen interactions seem to be more complex than mere colonization of the plant tissue. The environmental conditions and the plant genotype are key factors affecting the T39-induced resistance.

Complementary DNA (cDNA) libraries were constructed, starting from 1 µg of total RNA, at the Functional Genomic Center Zurich (FGCZ) following the TruSeq RNA Sample preparation protocol v. 2 instructions (Low Throughput protocol, Illumina, Inc.). The quality of the isolated RNA was further determined with a Qubit® (1.0) Fluorometer (Life Technologies, California, USA) and a Bioanalyzer 2100 (Agilent Technologies). Only those samples with a 260 nm/280 nm ratio between 1.8–2.1 and a 28S/18S ratio within 1.5–2 were further processed. The TruSeq RNA Sample Prep Kit v2 (Illumina, Inc, California, USA) was used in the succeeding steps. Briefly, total RNA samples (1 µg) were poly A enriched and then reverse-transcribed into double-stranded cDNA. TruSeq adapters were ligated to double-stranded cDNA. Fragments containing TruSeq adapters on both ends were selectively enriched with PCR. The quality and quantity of the enriched libraries were validated using Qubit® (1.0) Fluorometer and the Caliper GX LabChip® GX (Caliper Life Sciences, Inc., USA). The products resulted in a smear with an average fragment size of approximately 260 bp. The libraries were normalized to 10 nM in Tris-Cl 10 mM, pH 8.5 with 0.1% Tween 20. Bar-coded libraries were spread over 4 Illumina lanes, avoiding biological replicates in the same lane to assure the same instrument variation for the entire experiment. The TruSeq PE Cluster Kit v3-cBot-HS (Illumina, Inc, California, USA) was used for cluster generation using 2 pM of pooled normalized libraries on the cBOT. Sequencing was performed on the Illumina HiSeq 2000 paired end at 2 x101 bp using the TruSeq SBS Kit v3-HS (Illumina, Inc, California, USA). RNA-seq reads were quality-checked with fastqc which computes various quality metrics for the raw reads. Reads were aligned to the genome and transcriptome with Tophat v 1.3.3. Before mapping the low quality ends of the reads were clipped (3 bases from the read start and 10 bases from the read-end). Tophat was run with default options. The fragment length parameter was set to 100 bases with a standard deviation of 100 bases. Based on these alignments the distribution of the reads across genomic features was assessed. Isoform expression was quantified with the RSEM algorithm (http://www.biomedcentral.com/1471-2105/12/323) with the option for estimation of the read-start position distribution turned on. The analysis of Tophat files was performed on the CLC Genomics Workbench v. 5.5.1 (CLC bio, Aarhus N, Denmark), following the manufacture instructions. Sequences were then analyzed with the RNA-seq analysis program of the CLC platform and mapped against unannotated M. x domestica 63541 genes set reference v. 1.0 (http://genomics.research.FEM.it/). The insert size for paired-ends reads was set between 150 and 250 bp and normalization of expression values was performed using RPKM values (Mortazavi et al., 2008). All other parameters have been kept at the default levels. The CLC Genomic Workbench was further used to perform a principal component analysis with all differentially expressed genes found in each cDNA library.

Low and high temperature are detrimental for pollen germination. 5 and 30°C were detrimental for pollen viability, which was reduced by 50% in average.
Multivariate analyses demonstrated that bacterial and fungal communities are affected by altitude, which acts as a complex physicochemical gradient. In fact, soil moisture, Al, Mg, Mn and clay content are changing with altitude and influencing the bacterial genetic structure, while in the case of fungi, soil moisture, B and clay content are found to be the main drivers of the community.. Qualitative ARISA revealed the presence of a stable core microbiome of operational taxonomic units (OTUs) within each transect, which ranged between 57 and 68% of total OTUs in the case of fungi and between 63 and 72% for bacteria. No seasonal effect on the composition of microbial communities was found, demonstrating that bacterial and fungal communities in vineyards are mostly stable over the considered seasons. Investigating the effect of temperature in microcosm experiment, isolating its effect from all the other parameters, we determined the presence of a direct effect of temperature, soil type dependent. The soil bacterial community was fluctuating under the effect of temperature fluctuations, while the fungal community was mainly stable. Soil warming did not have any effect on the microbial community as observed on field in the altitudinal gradient, where temperature was not the factor explaining the differences between the microbial community at 200 and 700 m a.s.l. Vineyards, as other temperate environments, are quite stable to subtle changes in soil temperatures in the range forecasted by the climate change events. Even if we did not find a direct effect of temperature on the soil microbial communities, temperature could indirectly affect the soil microorganisms, acting on plant cover, nutrients availability, soil moisture and plant exudation. The soil structure was the main determinant of the microbial community associated to the bulk soil also in presence of plants. Characterizing the microbial community associated to the studied weeds, we found that the different compartments (roots, rhizosphere and bulk soil) were colonized by qualitatively and quantitative different microbial structure, in particular on the roots. Differences in the microbial community associated to the rhizosphere and to the bulk soil were plant dependent. The structure of the microbial community associated to the roots was mainly determined by the plant species, while the soil type was the main determinant of the microbial community associated to the bulk soil. Weeds are not expected to particularly affect the bacterial community associated to the bulk soil in vineyards, while they could play a role shaping the fungal one.
In the experiment on the phyllosphere the data indicate that the biocontrol agent is strongly influenced by environmental conditions, and the efficacy is higher when conditions are close to its optimum. The phyllophere bacteria are strongly influenced by the biocontrol agent under its optimal conditions.

T1 D2: Identification for each crop of the quality parameters most likely influenced by climate change. (FEM). The quality parameters most likely influenced by climate change are soluble solids (°Brix), pH and acid content in grape, soluble solids or apple and strawberry (FEM)

T1 D3: Effect of temperature gradient on fruit quality under climate change scenarios (FEM).
No gradient effect is foreseen under climate change scenarios in Trentino.

T2 D3: A peer reviewed article describing the phenology and genomics of ontogenic resistance in relation to temperature (ETH).
Gusberti, M., Patocchi, A., Gessler, C., and Broggini, G. A. L. (2012) Quantification of *Venturia inaequalis* growth in Malus × domestica with quantitative real-time polymerase chain reaction. Plant Dis. 96:1791-1797.

T2 D3: Linear model describing the development of the ontogenic resistance of leaves in relation to temperature (ETH).
The linear mixed model (performed using JMP v. 8 on windows vista (see also web site EnviroChange documents)

A linear mixed model for repeated measures was used to assess the effect of time, temperature, leaf position, treatment, and experiment on leaf's relative growth rate using the Restricted Maximum Likelihood (REML) estimation method. The square root transformation of RGR values was used to reach normal distribution of residuals and equal variance across groups. Data below 0.00001 RGR were excluded from the analysis to avoid excessive zeroes in the dataset. Leaf position, time points, temperature, treatment (inoculated and not inoculated plants), experiment (one and three years-old plants), and interaction of temperature*leaf position where considered as fixed factors. Leaf position nested within subject (shoot) was considered as random factor.

Effects	**DF_n**	**DF_d**	***F-ratio***	***P>F***
Leaf position	4	267.4	114.855	<.0001
Dpi	7	1800	558.495	<.00005
Temperature	4	328.9	16.982	<.0001
Treatment	1	320.6	42.555	<.0001
Experiment	1	397.6	22.033	<.0001
Temperature x Leaf position	16	318	1.473	0.1076

DF_n: Degree of Freedom numerator defined as number of groups analyzed minus 1.
DF_d: Degree of Freedom denominator defined as the number of subject observed minus the number of groups

REML Variance Component Estimates

Random Effect	**Var Ratio**	**Var Component**	**Std Error**	**95% Lower**	**95% Upper**	**Pct of Total**
SHOOT(ID)[LEAF POSITION]	-0.016206	-0.000069	5.6573e-5	-0.00018	4.1787e-5	-1.647
Residual		0.0042636	0.0001455	0.0039922	0.0045638	101.647
Total		0.0041945				100.000

-2 LogLikelihood = -5193.449858
(for model calculation: see ETH PhD thesis Gusberti no. 20883)

T3 D3: A peer reviewed article describing the dynamics of the induced resistance mechanism and its genomics in relation to temperature and drought stress (FEM).
Roatti B., Perazzolli M., Gessler C., Pertot I. Abiotic stresses affect *Trichoderma harzianum* T39-induced resistance to downy mildew in grapevine. Under review in Phytopathology: submitted February 11th 2013

T4 D2: A peer reviewed article on genotype-temperature interaction in the progamic phase in apples and strawberries (FEM).
Pertot I. Ress D. Climate change will not impact the progamic phase in apples and strawberries. In preparation. To be submitted to Journal of Botany.

T5 D3: One peer reviewed and one technical article describing the effect of temperature on presence and expression of OTA biosynthesis genes and OTA production by local strains under different temperature and duration of incubation (lead ETH participation FEM).
Storari M., Pertot I., Gessler C., Broggini G.A.L. 2010. Amplification of polyketide synthase gene fragments in ochratoxigenic and nonochratoxigenic black aspergilli in grapevine. Phytopathol. Mediterr. 49, 393−405
Storari Michelangelo, Broggini G.A.L., Bigler L., Cordano E., Eccel E., De Filippi R, Gessler C., Pertot I. ((2012) Risk assessment of the occurrence of black aspergilla on grapes grown in an alpine region under a climate change scenario. Eur J Plant Pathol.134:631–645.

T5 D3: One peer reviewed and one technical article describing the automated system of Ochratoxin risk identification through the RT-PCR and its validation (lead ETH participation FEM).
Storari M., Rudolf R., Gessler C., Pertot I., Broggini G.A.L. 2013. Detection of ochratoxin A-producing Aspergillus carbonarius and A. niger from grape using the loop-mediated isothermal amplification (LAMP) reaction. Journal of applied microbiology. Jan 18. doi: 10.1111/jam.12139.

T5 D3: A complete data set for OTA and grape, with appropriate mathematical models describing the temperature/duration relation to toxin quantity, gene transcription and fungal developments (measured as genome equivalents) to be used for risk scenario description (lead ETH participation FEM).
Data of a three-year survey consist of fungal isolate (no of identification), taxonomic name (as determined by sequences), ability to produce OTA and presence /absence of OT biosynthesis gene. Model as described originally by Batilani and implementation by Storari. OTA biosynthesis related Gene sequences. All Data are available in Storari M. (2012). Characterization and detection of mycotoxins producing black aspergilla from grapes grown in an alpin region Diss. ETH Z. No 20259: Chapter 2 & 3.

T5 D3: A protocol for high-throughput *Aspergillus carbonarius* contamination of grapes and OTA risk estimation" (ETH).
See protocol in Storari M., Rudolf R., Gessler C., Pertot I., Broggini G.A.L. 2013 Detection of ochratoxin A-producing Aspergillus carbonarius and A. niger from grape using the loop-mediated isothermal amplification (LAMP) reaction. Journal of applied microbiology. Jan 18. doi: 10.1111/jam.12139.

T6 D2-D3: one peer reviewed article on dependency of agro-ecological quality (described as biodiversity and biocontrol ability) on climatic conditions (FEM).
Corneo P.E., Pellegrini A., Cappellin L., Roncador M., Chierici M., Gessler C., Pertot I. 2013. Microbial community structure of vineyard soils across altitudinal gradients and in different seasons. FEMS Microbiology Ecology. DOI: 10.1111/1574-6941.12084

T6 D2-D3 one peer reviewed article on Biocontrol index for comparing functional activity of phylloplane microbial communities (FEM).
Storari M., Perazzolli M. Puopolo G., Antonielli L. Pertot I. Impact of environmental factors and biocontrol agents on natural microflora in the vineyard. In preparation. To be submitted to BMC genomics.
T6 D2-D3 one peer reviewed article on Biocontrol index for comparing functional activity of phylloplane microbial communities (FEM). (not achieved, biocontrol index was inconsistent and not applicable)

Highlight and justify task which are not carried out or carried out but not planned

FEM the Task 6 was modified for technical reasons (inconsistency of the biocontrol index).
ETH in ask 2 Instead of performing the genetic analysis in relation to ontogenic resistance on three cultivars using differential expression of genes we opted for a threefold repeat of a single cultivar. This for a better reliability of the obtained results. Unfortunately do to the high cost of RNA sequencing it was not possible to have 3 x 3 data sets..

Activity 3 Assessment of biophysical impacts of climate change at multitrophic level on crops

Objectives

Task 1. Identification of spatial and temporal dynamics of pest/pathogens of Trentino's major existing crops, their antagonists and their correlation with weather parameters.

To obtain a database (DB) of the existing information on pest and pathogens (P/P) of major Trentino's crops (gnoseological starting point of the project).

Task 2. Identification of spatial and temporal dynamics of pest/pathogens of selected alternative crops and their antagonists and their correlation with weather parameters.

Task 3. Production of EMs from exiting P/P forecast or epidemiological models, the objective is to adjust the existing EMs to be used in the ENVIRO tool.

Task 4. Retrieval of existing data on area, quality, production and P/P of Trentino's relevant crops

Assembling existing data sets originated from different sources and acquiring missing relevant data on pest and diseases, surface, production and quality of previously mentioned crops, for the validation of the available models with ENVIRO tool.

Task 5 Implementation of missing models for relevant P/P expected to be relevant in the selected scenarios

Task 6. Definition of intra and inter kingdom interactions and food web and their dependency on climate and evaluation of the extent of changes and/or the buffer capacities of the system on the existing relations and interaction under climate changes.

Task 7 Simulation of climate scenarios and their effect on tritrophic interactions among plant, pathogens and biocontrol agents under controlled conditions and comparison of different climates (Mediterranean and alpine) on selected combinations of biocontrol agents, pest/pathogens (artificial inoculation) and crops and on a biocontrol index.

T1: FEM will collect production, quality and P/P models, growth parameters and the information listed above for the DB construction.

FBK will collaborate with software tools to accelerate data preparation and integration.

T2: After FEM and FBK will downscale at regional level (RCM) the general circulation models (GCM) and/or propose some selected scenarios, based on the climatic requirements options for new crops/varieties will be provided by ARO; UNITN will furnish indications on the most suited alternative crops/varieties potential market and existing socio-economic situation of Trentino's agriculture. ARO will furnish information on P/P and agronomical requirement of alternative crops/varieties in changing scenarios.

T3: the model adjusting for ENVIRO inclusion will be done by FEM and ARO together and FBK will provide technical assistance.

T4: FEM will collect data on previous seasons from growers associations, cooperatives, extension service (CAT) and researchers of FEM on quality, P/P of existing Trentino's crops (grapevine, apple, berries). Collection of historical data pool on P/P and quality will be used for the validation of models in ENVIRO tool (FEM). UNITN will provide assessment of economic impact of new P/P and change of ratio of existing ones (together with Activity 5). FBK will provide algorithms to support selection of data and model tuning.

T5: FEM, and possibly ARO will develop models for 1-2 poorly investigated P/P per each crop (apple, grapevine, berries).

T6: FEM will deal with grapevine and soil model system, ARO with tomato, growth chamber experiments (single climate factors). In particular for the improvement of model systems to study multitrophic interactions, three models will be studied: an easy growing annual plant (alternative crop, tomato) (ARO), and perennial plant (existing crop, grapevine) (FEM) and soil (FEM), 2-3 pest/pathogens (B. cinerea, P. infestans O. neolycopersici ARO; E. necator, P. viticola (FEM) 3 biocontrol agents(most likely strains B52, Y13 and T39), 2 common leaf saprophytes (i.e. Alternaria sp., yeasts) in a pest/pathogen free greenhouse (FEM) or growth chambers (ARO) will be used. In the independent and combined effect of parameters and climate scenarios tomato will be studied by ARO and grape by FEM. FBK will provide data from climate scenarios.

T7: Selected climate scenarios on tomato and reaction to Mediterranean climate will be studied by ARO and selected climate scenarios on grapevine and reaction to Alpine climate will be studied by FEM. FBK will provide simulation and data analysis.

Activities

Task 1 and Task 2 have been carried out in the first two years.

Task 3

We implemented the model for powdery mildew of strawberry.

Task 4

We implemented the model of apple bloom thank to the data furnished by CTT-FEM.

Task 5

FEM We selected a pest (*Drosophila suzukii*) and two pathogens (*Phomopsis mali* and *Rosellinia necatrix)* which have been expected to be relevant in the selected scenarios and we implemented the missing models. The data were collected based on field observations and experiments under controlled conditions.

Task 6

FEM Since now the complex analysis of definition of intra and inter kingdom interactions and food web and their dependency on climate was extremely difficult. The two plant model systems constituted of an easy to grow annual plant ('alternative crop', tomato), and a 'perennial plant' (existing crop, grapevine) were studied. We studied 2 pathogens, 2 biocontrol agents, and all common leaf saprophytes in a pest/pathogen free greenhouse or growth chambers. Suspensions of sporangia (*Phytophthora infestans*) and conidia spray (*Oidium neolycopersici*) were applied as inoculum, separately, on tomato leaves. *Erysiphe necator, Plasmopara viticola* were inoculated on grapevine. Lesion development or severity of infection was followed during time. Representatives of bacteria, and yeast (B52, Y13) that are effective in controlling those diseases were used as biocontrol agents. Establishment of the microorganisms on plant leaves was assessed by counting their population density (CFU or RT-PCR) over time. Their antagonist activity was tested as control efficacy against the target diseases. Their side effect on the plant growth was tested. Independent effects of single parameters i.e. temperature, relative humidity, rain, water stress, and combinations of these parameters, on single pest/pathogen, biocontrol agent and plant and their combination: four temperatures (in the range of 15-30°C), four RH levels (70-99%), a set of simulated rain periods, three levels of water stress will be tested on the infection ability of each pathogen, on survival of biocontrol agent populations and on plant growth (composition, photosynthesis, dry weight and leaf surface). We studied the effect of climatic factors on combinations of multiple pest/pathogen, biocontrol agent and plant. Selected pathogens (2) and biocontrol agents (2) were applied at the same time and will be followed for two weeks under conditions that combine general scenarios (previously identified) i.e. low temperature (15°C) combined with simulated rain (10 mm every day) vs. higher temperature (30°C) simulated rain (3 times 50 mm 5 day interval). The two regimes had a strong effect on the pathogens as well as on the two biocontrol agents. In another system evaluated the influence of low/high temperature combined to reduced watering on the interaction between *B. amyloliquefaciens* strain S499, pathogens (*Podosphaera xanthii, Botrytis cinerea and Phytophthora infestans*) and plants (tomato, zucchini, bean) resulting in the induction of systemic resistance (ISR). A third model system (soil) potted strawberry plants, soil treated with *Trichoderma atroviride* and *Armillaria mellea* was studied. Population dynamic of the pathogen, the biocontrol agent and the natural community were compared in sterilized and non sterilized soils under different soil temperatures (15° and 25°). Disease incidence, biocontrol activity and *T. atroviride* presence was monitored after 6 months. DGGE was used on soil samples collected over time, to test relative changes in natural microbial populations. A synthetic soil was implemented and populated by 12 microorganisms commonly found in soil and whose genome is available. The genome of *T. atroviride* was available. *A. mellea* was sequenced. The pathogen and the biocontrol agent have been introduced in the synthetic soil system. RNA was extracted, cDNA obtained and sequenced. To study the interaction among *A. mellea* and *T. atroviride* we developed a new method. The study of the interactions among microorganisms, especially between pathogens and other

microorganisms, is a very useful way to identify possible biocontrol agents (BCAs). In this study we verified the capability of delta C-13 analysis using isotope ratio mass spectrometry (IRMS) to detect active parasitism or metabolic assimilation of C-13-labeled *A. mellea* (plant pathogen) by *Trichoderma atroviride* and *Pseudomonas fluorescens* (two BCAs). The three microorganisms were labeled in pure-culture using a specific medium to which D-glucose C-13 was added. The delta C-13 analysis of mycelia/ cells and DNA was undertaken using IRMS at different times, to study the uptake kinetics of C-13. The mechanisms of interaction were studied by implementing dual-culture tests and measuring the delta C-13 values of the two BCAs after 29 days of contact with the labeled pathogen.
We simulated two climate scenarios under controlled conditions and tested them on the interaction of players in the multitrophic system. The multitrophic interactions in the model systems was the previously mentioned. The development of the two pathogens on the plants was modeled.
The potential of biocontrol activity was not evaluated the biocontrol index (already developed for late blight on potato, FEM unpublished results) because on grapevine it did not gave consistent results.
ARO
Modelling the epidemic of two diseases and their biocontrol agents under different climate.
We researched whether we expect more powdery mildew (PM) than late blight (LB) / downy mildew in the future if climate will be warmer? Are the two diseases influencing each other in presence of biocontrol agents? How fast is the developing of the epidemic if the diseases are present solo or in combination? We hypothesized that under warmer climate a common disease of warm climates is prevailing on a diseases of cold climates in quantity and distribution.
The two diseases PM and LB in a population of tomato plants each alone or the two together were initiated by placing a diseased, sporulating tomato plant close to a population of healthy tomato plants. A mixture of biocontrol agents was sprayed (B52 and Y13). Each group of plants was overhead irrigated (5 mm/h, for 3 h, every 3 day) and air movement was also operated. Plants were kept overnight at 100% RH. Two weather conditions: high (25°C) and low (18°C) temperature were a major parameter in the experiment to simulate climate effect.
Microbial populations. Both BCAs were applied together and their individual populations were evaluated on the tomato leaves in the two climates (two temperatures) and on the various infected plants (no infection, PM, LB).

Describe activities carried out by subcontractors
Sequencing of RNA have been carried out by an external company

Results
D. suzukii development is positively related to relative humidity and temperature, *P. mali* is strongly related to temperature fluctuation in late winter and early spring and *R. necatrix* development in soil is strongly reduced by high soil water content water and low temperatures, while high temperatures and low water content promote its development.
The bacterium B52 was strongly affected by high temperatures and low RH and disappears after few days. The yeast Y13 is more resistant to high temperatures and low RH. Powdery mildew increases the survival of the bacterium either by providing a physical shelter or nutritional factors which can sustain the growth of the bacterium. No side effect on the plant have been detected.
A reduced level of ISR efficacy was observed when plants were submitted to stress before bacterization, but root treatment with S499 prior to stress exposure attenuated such negative effect. Colonization of S499 during exposure to stress globally allowed the three plants to conserve their ability to mount defense lines to a similar degree at all tested temperatures. Further investigation revealed that production of the ISR elicitor surfactin by S499 is clearly enhanced at low temperature allowing to counter-balance the reduced rhizosphere fitness (colonization, motility, biofilm formation) observed under cold.
In the soil system no significant changes in pathogen populations and Trichoderma have been highlighted between the two temperatures. Therefore we implemented a more sophisticated model

system, which allowed us understanding the major changes in the artificial soil populations in presence of the pathogen or the biocontrol agents.
A. mellea absorbed C-13 more slowly (plateau at 21 days) than *T. atroviride* and *P. fluorescens* (3 and 1 day, respectively) in pure-culture. The maximum delta C-13 values were higher in A. mellea and *T. atroviride* mycelia (8,019.9 parts per thousand and 10,383.7 parts per thousand, respectively) than in *P. fluorescens* (953.4% in cells). In dual-culture the mycelia of *T. atroviride* which remained in direct contact with labeled A. mellea showed an increased delta C-13 value with respect to the unlabeled treatment (66.4% and -26.6 parts per thousand, respectively), due to active interaction. Lower assimilation of C-13 was detected in *P. fluorescens*.
In general, the bacterium B52 and the yeast Y153, each had higher population level in the higher temperature as compared with the lower temperature. The presence of each of the pathogens on the plants promoted the populations of each of the biocontrol agents. Moreover, the presence of both pathogens on the tomato plants allowed even a significantly 5-10 times higher population of the bacterium and the yeast. In conclusion, both climate and the pathogens affected the populations of both pathogens BCAs.
Similar results have been obtained by ARO on tomato.

T2 D3: A list of pest and pathogens reported on the selected alternative crops and available models for spatial and temporal dynamics of pests/pathogens on alternative crops from literature was created (ARO).

T2 D3: A list of effective control measures and known biocontrol agents/hyperparasites of pests/pathogens of grapevine, apples, berries was prepared (FEM-ARO).

T3 D1-D3: Some P/P physiological models to be used in the ENVIRO tool have been adapted and validated; powdery mildew of grape, *Lobesia botrana*, fireblight of apple, powdery mildew of strawberry (FEM-FBK).

T3 D2 The most economically important P/P present in Trentino or potentially immigrating to Trentino have been identified in *Drosophila suzukii, Phomopsis mali* and *Rosellinia nectrix* (FEM-ARO).

T4 D3: Prototype tested and 1 scientific publication together with Activity 1 (ALL).
ENVIRO was validated and a publication was produced:
Caffarra, A., Rinaldi, M., Eccel, E., Rossi, V., Pertot, I. (2012) Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. Agriculture, Ecosystems and Environment 148, 89– 101.

T5 D3: Three models for poorly investigated P/P but potentially becoming epidemic in Trentino have been built (FEM-ARO).

T5 D3: Minimum of one peer reviewed article on biology or epidemiology of P/P (FEM-ARO).
Cini, A, Ioriatti, C, Anfora, G, 2012. A review of the invasion of Drosophila suzukii in Europe and a draft research agenda for integrated pest management. Bulletin of insectology 65. 149-160.

T5 D2: Two peer reviewed articles: Identify the parameters that play a role in the model systems for studying the effect of multitrophic interaction (ARO, FEM)
Pertot I., Agra, O., Rav David, D., Elad Y Multiple interaction in complex systems: tomato and grapevine. Manuscript in preparation. To be submitted to Phytopathology.
Pertot I. Puopolo G. Hosni T., Pedrotti L., Jourdan E., Ongena M. Modulation of surfactin production explains the success of the interaction between plants and Bacillus amyloliquefaciens S499 at different temperatures. Submitted to ISME Journal on February 27, 2013.

T6 D2: Two peer reviewed articles on the effect of relevant parameters on the interactions of the multitrophic systems, (ARO, FEM).
Pellegrini, A, Corneo, PE, Camin, F, Ziller, L, Tosi, S, Pertot, I 2012. Studying trophic interactions between a plant pathogen and two different antagonistic microorganisms using a C-13-labeled compound and isotope ratio mass spectrometry. Rapid communication in mass spectrometry. 26: 510- 516.
Pellegrini, A., Corneo, P., Camin, F., Ziller, L., Tosi, S., Pertot, I. 2013. Isotope Ratio Mass Spectrometry identifies soil microbial biocontrol agents having trophic relations with the plant pathogen *Armillaria mellea*. Applied soil ecology, 64, 142-151.

T7 D3: One peer reviewed article on comparison of the model systems in two natural environments, how can climate influence tritrophic interactions (current alpine environment, S. Michele, and Mediterranean climate, Tel Aviv) (ARO, FEM).
Pertot I., Elad Y., Dolci C. Merler S. The influence of climate on combines infections of pathogens on grapevine and tomato. Manuscript in preparations. To be submitted to applied environmental microbiology.

Highlight and justify task which are not carried out or carried out but not planned/ evidenziare e motivare le eventuali tasks non realizzate o realizzate ma non previste originariamente;
Because of reduction of funding and as recommended by the reviewers the Task 8. Interaction between insects and their pathogens was not carried out.

Activity 4 Development of highly innovative tools for adaptation in crop management (i.e. expert systems, decision support systems, biocontrol agents, vibration based mating disruption, etc.) to the forecasted/expected changes.

Objectives

Task 1 Identification of suitable adaptation strategies to be applied in the most likely future scenarios to preserve quality and suppress P/P.

Task 2 Scaling-up from prototypes to field applications.

Task 3 To implement a web-based platform to include, manage and optimize the adaptation tools developed in the previous tasks.

Task 4 Identification and analysis of agronomic feasibility of new adaptation tools (as new varieties obtained by marker assisted breeding for traits of interest, trans or cis-genic varieties, new agronomical technologies, new land use, etc.) that may be suggested in a view of climate change in the future (50-100 years).

Role of participants

T1 and T2: FEM will develop innovative crop protection adaptation tools (like electrolyzed acid water, vibrational and pheromonal mating disruption, mechanism-selected microbial biocontrol agents). ARO will develop innovative crop protection adaptation tools (like effective and low impact pesticides, alternative means of control, decision support systems, etc.), agronomical practices, use of alternative crops (such as tomato, cucumber, potato, highly value crops), alternative cropping and irrigation systems.

T3: FEM will develop a web-based platform to optimize management of effects of climate change for Trentino's growers.

T4: In this task we envisage the collaboration of all participants with their own specific expertise (FEM, ARO, ETH, FBK and UNITN).

Activities

Task 1

ARO

Crop protection adaptation tools included the *T. harzianum* T39 BCA and biochar working against plant pathogens. Induced systemic resistance against gray mold in tomato by benzothiadiazole and *T. harzianum* T39. *B. cinerea* is a tomato pathogen world-wide. We studied defense-related gene expression involved in the induced resistance against *B. cinerea* in tomato plants by the control agents benzothiadiazole (BTH) and T39. In whole plants transcriptional changes related to salicylic acid and ethylene were induced by BTH. Drenching T39 caused jasmonic acid related changes. Drenching T39 suspensions lead to enhanced resistance to *B. cinerea* which was proportional to the concentration of T39 (62-84% disease reduction by 0.04-0.4%). Interaction between *B. cinerea* infection and control agents treatment in detached leaves revealed that drenching with T39 suspensions induces systemic resistance against *B. cinerea* and priming of salicylic acid and ethylene-related gene expression proportionally to the fungus concentration. In the same system BTH induced resistance to gray mold independently of salicylic acid and led to strong priming of two genes known for their role in defense against *B. cinerea*, Pti5 and PI2.

Induced systemic resistance in tomato by biochar soil amendment. Biochar, a solid product of biomass pyrolysis is a novel control agent inducing systemic resistance to foliar pathogens in various plants when amended into the soil. Recently, defence related transcriptional modifications consecutive to biochar amendment have been described in strawberry and in tomato. To dissect the induced resistance pathway mediated by biochar in the tomato – B. cinerea pathosystem, we studied (a) the effect of genetic variations affecting salicylic acid (SA), ethylene (ET) or jasmonic acid (JA) response to biochar-mediated induced resistance (b) the variations in the early cellular response of H_2O_2 burst associated with biochar-mediated resistance and (c) the transcriptional changes of 13 defence-related genes induced by biochar amendment upon B. cinerea inoculation on detached leaflets. Amendment of potting mix with greenhouse waste biochar produced at 450ºC resulted in

ca 50% reduction in disease severity in all tested genotypes except in a jasmonic acid deficient mutant, def1, which did not respond to biochar-mediated induced resistance to *B. cinerea*. We observed stronger and earlier H2O2 accumulation as a result of the biochar amendment subsequent to *B. cinerea* inoculation, and a disruption of this effect by the def1 mutation. Finally, while transcriptional changes due to biochar amendment and infection varied with the tomato genotype, the genes Pti5 and Pi2, which are known as crucial elements in resistance against *B. cinerea*, were generally upregulated by the combination of biochar and pathogen infection at a higher rate (priming) or at a similar rate than infection alone.
Biochar characteristics may affect disease suppression. Biochar addition to the potting mixture of cucumber and bean plants suppressed disease caused by *R. solani*. Optimum disease suppression was obtained at the lower biochar loading. Eucalyptus biochar was more effective than greenhouse waste biochar and each feedstock have a different optimum concentration for disease control. Effect of biochar on plant growth parameters of cucumber and bean inoculated with *R. solani* had similar pattern to the disease suppression curve. However, in many cases there was no difference between the conc. of biochar. Plant growth of cucumber and bean grown in pathogen free growth medium were increased linearly with increasing biochar concentration for EUC350, EUC600, and GHW350 biochar.
FEM
SCNB2, *A. quisqualis* ITA3 and its activator, *L. capsici* PG4 have been tested. Greenhouse trials have been carried out on strawberry powdery mildew and cucurbits powdery mildew. Field trials have been carried out on grapevine powdery mildew and grapevine downy mildew. Randomized block design with at least 4 replicates was used. Greenhouse trials have been carried out twice or more, while only one field trial have been carried out for each grapevine pathogen. *A. quisqualis* ITA3 and its activators have been tested under greenhouse conditions. SCNB2, *A. quisqualis* ITA3 and its activator, *L. capsici* gave satisfactory and consistent results in almost all trials.

Task 2
We scaled up the FEM nutrient broth in collaboration with the company Manica. Trials have been carried out under field conditions on grapevine and in greenhouse on cucurbits. The DSS Sentinella was tested in a vineyard in S. Michele all'Adige in collaboration with the company R&D systems. Several trials have been carried out to find the best conditions for production of *A. quisqualis* conidia. The DSS is ready for themarket while SCNB2 should still be refined, because the NaCl content is still too high. *A. quisqualis* ITA3 still needs industrial scale up, since the methodology developed so far can be suited only for small scale field trials.

Task 3
A platform, called Monberry was developed. The platform allows managing treatments for each single field plot and gives recommendation to growers. The web implementation was carried out in collaboration with the University of Haifa. The web platform can be now tested by growers.

Task 4
A study was complete by FEM, ARO, ETH to identify the potential tools to be applied in the future to counteract the effect of climate change on plant protection. The most suited tool is represented by resistant cis-genic plants. However costs and regulatory burdens should be taken into consideration. The more realistic tools are currently the biopesticides and the DSS to optimize treatments.

Deliverables
T1 D3 Means to suppress P/P that are intensified with climate change (FEM-ARO).

- *T. harzianum* T39- a fungal biocontrol agent from ARO,
- acibenzolar-S-methyl (BTH, Bion),
- SCNB2, originally developed in collaboration between FEM and ARO
- a bacterium B52, a FEM isolate
- a yeast Y153, an ARO isolate

- Various biochars
- *quisqualis* ITA3
- *L. capsici* PG4
- An activator of ITA3

T1 D3 Alternative agricultural systems (FEM-ARO).
As climate is warming up, it is expected that larger areas in Trentino will be exposed to higher temperatures, more sunny days, shorter winter and longer summer. Conditions in the fall and spring will be milder. In some areas it will be possible to grow in the open some field crops or fruit trees that originate from warmer regions and greenhouse crops. A list of suggested crops and current varieties that fit the new climatic scenario was formed, yet with potential pests and diseases. Among the alternative crops are tomato, cucumber, potato, and other highly valuable agricultural plants.

T1 D3 At least two peer reviewed articles on environmentally sound means to suppress P/P (FEM-ARO).
Elad Y., Rav David D., Meller Harel Y., Borenshtein M., Ben Kalifa H., Silber A. and Graber E.R. 2010. Induction of systemic resistance in plants by biochar, a soil-applied carbon sequestering agent. Phytopathology 100, 913-921.
Graber E.R., Meller Harel Y., Kolton M., Cytryn E., Silber A., Rav David D., Tsechansky L., Borenshtein M. and Elad Y. 2010. Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. Plant and Soil 337, 481–496.
Kolton M., Meller Harel Y., Pasternak Z., Graber E.R., Elad Y. and Cytryn E. 2011. Impact of biochar application to soil on the root-associated bacterial community structure of fully developed greenhouse pepper plants. Applied and Environmental Microbiology 77, 4924-4930.
Graber E., Silber A., Elad Y., Meller Harel Y., Rav David D., Borenshtein M., Shulhani R., Ben Kalifa H. (2011) Induced systemic resistance in plants by soil applied biochar. Shadeh Vayerek 228: 26-32. In Hebrew
Elad Y., Cytryn E., Meller Harel Y., Lew B. and Graber E.R. 2011. The Biochar Effect: plant resistance to biotic stresses. Phytopathologia Mediterranea 50, 335−349. *Review publication*
Meller Harel Y., Elad Y., Rav-David D., Borenstein M., Shulchani R., Lew B. and Graber E. R. 2012. Biochar-induced systemic response of strawberry to foliar fungal pathogens. Plant and Soil 357, 245-257.

T2 D3 Scale up of prototypes, products (FEM).
SCNB2 was scaled up in collaboration with the company Manica.

T3 D3 Prototype of a web-based platform for managing P/P control and quality under climate change; user evaluation (FEM).
Indentificator was developed to help growers to visually identify new pest and pathogens
Sentinella was developed in collaboration with the company R&D systems to manage crop protection on grapevine
Monberry was developed as a platform to manage pest and pathogens on several crops, it was studied on the case study of strawberry

T4 D3 Technologies that could be implemented as adaptation tools in the long term scenario, with cost/benefit and acceptance analysis (FEM-ARO-UNITN).
A list of possible strategies and technologies was prepared: cis-genic resistan plants, biopesticides and DSS are the recommended tools to counteract the effect of climate change on pest and pathogens.

Activity 5 Assessment socio-economic impacts of the most probable scenarios and evaluation of adaptation strategies that can be taken

Objectives

The socio-economics impact of the climate change will be outlined, focusing on the effects of climate changes on crop management and land use change.

Task 1 Assembling existing dataset originated from different sources (Farm Accountancy Data Network (FADN-RICA), research centres, cooperatives, extension service, etc.) and acquiring data on spatial coordinates of the farms producing grape and apples in order to construct a fully georeferentiated dataset.

Task 2 Evaluation of the spatial and temporal variability in crop yield and farm income (both calculated from farm accountancy) with respect to climate related variables during the reference period (2003-2007).

Task 3 Understanding the farmer's perception of climate change, how they are affected by climatic conditions, their acceptance of the adaptive strategies that are available to them, and the constraints and opportunities for enhancing their adaptive capacity.

Task 4 Modelling the farmers behaviour in response to climate variation and to the consequent change in pest ecology (type and density)

Task 5 Evaluation of the overall sustainability of the proposed adaptation strategies at the farm and at provincial level.

Task 6 Evaluation at the provincial level of the social acceptability of the proposed adaptation strategies

Task 7 Evaluation of potential alternative crops in case of extreme events in Trentino

Role of participants

T1: UNITN extractS the farm sample from the INEA dataset on Farm accountancy and assemble all the data in a single dataset; FEM supervise the selection of agroeconomic and meteorological factors; FBK geocoding and integration of farm accountancy data within ENVIRO.

T2: UNITN will implement the analysis and identify the different groups of homogeneous farms

T3: FEM will provide the list of adaptation strategies available; UNITN will prepare, pre-test and perform the survey and elaborate the observed data and will assess the farmers' risk attitude

T4: FEM provides a crop model which highlights the effect of climate change and pests and diseases evolution on crop yield in Trentino; UNITN: implement the bio-economic simulation farm model

T5: FEM calculates the costs for farmers; UNITN will implement the trade-off analysis that will form the starting point for policymakers to create an adaptive policy. FBK will provide geographical scenarios of bio-economic impact.

T6: UNITN will perform a choice experiment in order to evaluate the social acceptability of different adaptive strategies

T7: FEM and UNITN will jointly simulate the effects of an extreme event. FBK will provide technical support.

Activities

<u>Task 2</u>

New model estimations according to the Ricardian approach were performed in order to look for more robust results. We separate irrigated from non irrigated farms and new models were estimated only on irrigated farms. This reduced the sample to 126 farms growing apple and grape in Trentino both in year 2003 and 2006. Estimations results are more robust and the relationship between net revenues and temperature assumes the usual hill-shape form. In the new models we also tested for spatial correlation.

A second round of estimations exploits the nature of unbalanced panel of our sample with 291 farms and 886 observation. The approach is different from the Ricardian one because we focus on the annual weather effects instead of the long run effect of climate following the example of Kelly

et al. (2005) and Deschenes and Kolstad (2011). We specify a fixed effect panel data model using an estimator robust respect to heteroskedasticity and correlation, and apply a variables' specification that give us the possibility to consider important time-invariant farm's aspects (i.e. soil typology and slope) among regressors. Also in this analysis we test for robustness of our model respect to spatial correlation.

Task 3

A dataset containing 195 complete and usable observations concerning 75 winegrowers and 120 apple farmers collected in spring 2011 is elaborated in order to test different hypotheses of farmers' behavior. To this end several econometric models have been estimated. The objective of this econometric analysis is to explain farmers' perceptions of climate change related risks.

Hail risk and crop disease risk perception in the short-run (the then upcoming growing season, 2011) and in the long-run (a more remote future growing season, 2031) are analyzed. Regression analysis is used to test if farmers who believe in climate change show quantitatively higher perceptions of related hazards than farmers who do not believe in climate change. Our results confirm that farmers indeed relate climate change concerns to higher future hazards for their crops.

Further analysis of the experimental data on farmers' perceptions of long-run hail risk allowed us to investigate whether farmers use heuristics to form quantitative assessments of climate change related risks. Our results show a clear reliance of farmers on several heuristics, including availability and representativeness heuristics as well as biased assimilation.

In order to investigate the expert perception of climate change we adapted to the Trentino context the questionnaire kindly provided by some Danish researchers (Olesen et al. 2010). The questionnaire is structured as a Excel spreadsheet and is divided in 6 sections concerning: actual limiting factors, expected impacts of climate change, adaptation practices currently adopted by Trentino farmers, adaptation practices expected in the future, existence of alarm and decision support systems, overall perception of climate change and adaptation policies. Since the original Danish questionnaire was devoted to many different European crops, we had to tailor it to the Trentino viticulture by adding new limiting factors and new adaptation strategies. The respondents had to evaluate the different items using a Likert scales combining the degree of severity and the direction of effects (increase/decrease). The questionnaire was administered to 14 experts belonging to the viticulture advisory service of FEM. Data were collected between August and September 2011. These qualitative data are organized in tables and graphs. Statistical analysis was impossible because the small number of observations.

Task 4

The observations produced by apple farmers completing two stated preference experiments are organized in a new dataset containing 313 complete and usable observations about apple farmers' actual insurance decisions. These data are used for estimating several econometric models to assess whether there is a relationship between risk aversion and subjective probabilities belief of the probability of crop losses due to weather events.

Regression analysis is used to investigate the relationship between a farmer's level of risk aversion and his subjective belief of the probability of crop losses.

A Probit model estimation is used to test the predictive power of different format of risk attitude elicitation. Actual insurance purchase decision is the dependent variable to explain and risk attitude measures elicited with three different formats are used as explaining variables.

Part of the data collected in the context of task 3 (subjective beliefs and perceptions) could be used to complement data collected in the context of task 4 (weather insurance decisions) to achieve the objectives of task 4. To this end, we used econometric analysis in a discrete choice experiment framework to assess farmers risk aversion using data on insurance actual decisions and farmers' subjective beliefs. The analysis also assesses which farmer and farm characteristics are relevant to predict risk attitudes. In addition this analysis shed light on the ability of subjective believes to play a role in improving empirical estimates of risk aversion. Therefore this study represents a methodological contribution to the empirical literature on the measurement of individual risk attitudes.

Task 5

In order to test the suitability of the Dexipm for sustainability assessment, the tool has been applied to FEM farm as case study. Meeting with experts FEM provided economic and environmental data associated to the four strategies to be evaluated (variety switch from Mueller Thurgau to Chardonnay, crop switch from viticulture to cherry orchards, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones). Research desk and brainstorming sessions lead to the identification of 3 new indicators to be added to the Dexi tool for better cover the social dimension of sustainability. The indicators added to the attribute "farmer and employees knowledge and skills" are Awareness of ecological relationship, Representativeness in social institutions e Additional training. For collecting information about social sustainability indicators a questionnaire has been designed and administered to some experts. Quantitative data provided by FEM and qualitative indicators on social sustainability collected through the survey questionnaire were inputted by FEM into the Dexipm software tool.

Task 6

A choice experiment (CE) was designed by UNITN to investigate the population perception of having apples containing pesticide residues in 2030.

First, two focus-group interviews with 10 participants each were carried out to identify alternatives, attribute, and levels to be used in the ultimate Choice Experiment (CE) field survey. From the choice card we had to remove the attribute concerning the type of crop protection strategy (chemical, biological control, pest resistant varieties) because respondents focused their attention only on this attribute without examining the other attributes (number of apple containing residues and the probability) and this respondent's behavior is strictly to avoid in CE.

After a pre-test CE field survey on 80 subjects, the ultimate CE field survey was designed and the survey software was prepared. The survey contained a section for the elicitation, trough the EM method, of risk perception about the number of apples containing pesticide residues in 2030. FEM provided the expectations of risk infections of Fire Blight in 2030. The experimental design producing the choice cards is a D-efficient homogeneous pivot design that was generated by using Ngene 1.1.1. The final sample consists of 797 taxpayers who reside in the Province of Trento, 487 were assigned to the treatment group in which each subject is presented with a SQ alternative which incorporates her/his subjective risk estimate, while 310 in the other treatments where each subject is presented with a SQ's risk level which differ from her/his subjective risk estimate. Data were collected by trained interviewers from OGP using the computer-assisted personal interviewed (CAPI) system which consists in face-to-face interviews usually conducted at respondents' home or business via laptop. Data obtained from each subject were automatically stored in a central computer. Data were analyzed using Pythonbiogeme 2.1.

Describe activities carried out by subcontractors

OGP administered the computer assisted face-to-face survey to a sample of 797 taxpayers in the entire province of Trento. UNITN provided OGP with the laptops where the questionnaire was uploaded.

Results

The Ricardian model estimations on 126 farms growing apple and grape in Trentino both in year 2003 and 2006 highlight an expected negative impact of climate change on Trentino farms. The analysis of the full panel of 291 irrigated farms confirms a hill-shaped relationship between farm profitability and annual weather effects (temperature and precipitation). Moreover, net revenue per hectare depend heavily also on farmer's age and on the values of variables connected with farmer's strategies such as specialization and quality certification and insurance subscription.

Most of interviewed farmers stated to believe in climate change. Farmers who believe in climate change have higher quantitative perception of future hazard to their farming operation that are directly or indirectly related to climate change. Perceived average long-run risk (2031) exceeds the short-run risk (2011). Farmers who are more (less) risk averse tend to perceive greater (smaller) probabilities of farm losses occurring.

From a methodological point of view we find that only a gamble task defined in terms of farm income is good in predicting farmers insurance purchase decisions.
From a methodological point of view we show how subjective beliefs can be fruitfully employ to improve empirical estimates of risk aversion.
Climate change is not perceived to impact a great deal on the Trentino agriculture according to the viticulture experts and no big changes in adaptation practices are expected. Only incidence of hail risk is perceived to increase.
From the DexIPM application it emerged that the selected adaptive strategies (variety switch, crop switch, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones) result to be overall sustainable and the differences in terms of sustainability among the selected adaptation strategies are very small.
From the choice experiment carried out on Trentino population taxpayers emerge that dwellers expect that the number of apples containing residue will be 75 out of 100 in 2030. The willingness to support pay for R&D programs for developing innovative methods to control the spread of new apples diseases due to climate change depends on the number of apples containing pesticide residues, on risk attitude, time preferences, net annual income, being an apple consumer or producer, and consumer association membership. The marginal WTP for a reduction from 75 to 15 apples containing pesticides is around 1,2 euro per taxpayer per year. The experiment put new light on the effects of risk information provided in the Status Quo on choice behavior. We found that subjects provided with risk that are lower than perceived ones, adjust attribute levels on their expectations, and express marginal WTP for risk reduction higher than those that they would have provided taking choices by using the SQ's risk level. In contrast, subjects who face a risk of having contaminated apples higher than the expected one, do not revise attribute levels on their expectations, but, they, driven by some sort of alarm, irrationally pay more than what they would have paid if they fully accepted the SQ's risk level.

Deliverables
T2 D2: one peer reviewed article on the effect of climate on economic performance of homogeneous groups of farms. (100% achieved)
De Salvo M. Raffaelli R. Moser R. The impact of climate change on permanent crops in an Alpine region: A Ricardian analysis, accepted for publication (with minor revisions) to Agricultural System
De Salvo M. Raffaelli R. The effect of annual weather on permanent crops in Trentino, paper under preparation

T3 D3: one peer reviewed article on Analysis of farmers' perception of climate change and one peer reviewed article on willingness to adopt different mitigating/adapting strategies (80% achieved)
Menapace L., Colson G. Raffaelli R. Cognitive Heuristics and Farmers' Perceptions of Risks Related to Climate Change, paper presented to Agricultural & Applied Economics Association in Seattle August 2012 (paper in preparation for journal submission)
Menapace L., Colson G., Raffaelli R. Do individual risk attitude measures predict insurance decisions? submitted to Journal of Economics Behaviour & organization

T3 D3: several bio-economic farm models for different groups of farms (deleted because the necessity to change the methodological approach)
The redefinition of the content of task 4 in term of a new methodology implies the renouncement to estimate bio-economic models. Farmers' behaviour in response to the risk and uncertainty will be investigated with other models.

T4 D3: one peer reviewed article on Modelling farmers' behaviour in response to risk and uncertainty associated to climate change
Menapace L., Colson G. Raffaelli R. (2012) Risk Aversion, Subjective Beliefs, and Farmer Risk Management Strategies, American Journal of Agricultural Econonomics doi: 10.1093/ajae/aas107

Menapace L. Fezzi C. Estimating risk preference from insurance choices using subjective beliefs, paper under preparation

T5 D3: one peer reviewed article on the sustainability of different strategies
Rizio D., Raffaelli R., Colombini A. Pertot I Evaluation of overall sustainability of selected adaptation strategies in viticulture with Dexipm. (Paper in preparation),

T6 D3: two peer reviewed articles, one on the results in terms of the willingness to accept or to support the different adaptation strategies the other on the methodological issues related with the design of the choice experiment (80% achieved)
Moser R., Raffaelli R. (2012) Consumer preferences for sustainable production methods in apple purchasing behaviour: a non-hypothetical choice experiment. International Journal of Consumer Studies, 36 (2) p141–148 DOI: 10.1111/j.1470-6431.2011.01083.x
Moser R., Raffaelli R., Testing Hypothetical Bias with a Real Choice Experiment Using Respondent's Own Money" submitted the second revision to the European Review of Agricultural Economics
Cerroni S. THE INCORPORATION OF SUBJECTIVE PROBABILITIES INTO CHOICE EXPERIMENTS TO TEST SCENARIO REJECTION. Chapter IV of the Phd Thesis .
Cerroni S. Notaro S. Raffaelli R. Introducing subjective probabilities into choice experiments to test scenario adjustment, Paper under preparation and abstract submitted to in International Conference of Choice Modelling Sidney 2013
The delay in preparing the deliverables associated to the final choice experiment is due to the fact that the survey was administered in February and March 2012 and data were provided by OGP at the beginning of April. Survey data required to be organized into a dataset, verified and then elaborated with sophisticated econometric softwares.

Other deliverables:
Cortelletti M. Raffaelli R. Cambiamento climatico e pratiche di adattamento nella viticultura trentina. L'opinione degli esperti. Internal report

T7 D3: a peer reviewed article on the study of the potential crops that could substitute existing crop in case of extreme event and peer reviewed article on the analysis of the future impact of these new alternatives.
The article is in preparation.

Highlight and justify task which are not carried out or carried out but not planned
As mentioned in section 1 ii) and 2 ii), the deliverable T3 D3 (several bio-economic farm models for different groups of farms) was impossible because we had to change the approach to deal with farmers behavior modeling.
Task 7 was eliminated since the beginning of the project because of budget reduction. We add the qualitative survey on experts in order to gather additional information on the perception of climate change impact from another point of view. A master student (Cortelletti Massimiliano) devoted his thesis to this survey.

Deliverables

WP	task	year	deliverable	Description of the status/additional information	partner	%
1	T5	D3	Visualization of vulnerable host areas, ranges of expansion and climatic limits of P/P, under current and global warming scenarios.	Achieved	FBK FEM	100
1	T1-	D3	peer reviewed articles on ENVIRO and its applications.	Caffara et al., 2012	FBK FEM	100
1	T3	D3	peer reviewed articles on ENVIRO and its applications.	In preparation, Rinaldi et al., fire blight to be submitted to …	FBK FEM	100
2	T1	D3	Effect of temperature gradient on fruit quality under climate change scenarios (grape, sugars)	Achieved	FEM	100
2	T2	D3	A peer reviewed article describing the phenology and genomics of ontogenic resistance in relation to temperature	Achieved	ETH	100
2	T2	D3	Linear model describing the development of the ontogenic resistance of leaves in relation to temperature	Achieved	ETH	100
2	T3	D3	A peer reviewed article describing the dynamics of the induced resistance mechanism and its genomics in relation to temperature and drought stress	Roatti et al., stress on ISR	FEM	100
2	T4	D2	A peer reviewed article on genotype-temperature interaction in the progamic phase in apples and strawberries	Paper on preparation only on apple pollen	FEM	80
2	T5	D3	One peer reviewed and one technical article describing the effect of temperature on presence and expression of OTA biosynthesis genes and OTA production by local strains under different temperature and duration of incubation	Achieved as scientific paper	ETH FEM	100
2	T5	D3	One peer reviewed and one technical article describing the automated system of Ochratoxin risk identification through the RT-PCR and its validation	Achived, Storari et al.	ETH FEM	100
2	T5	D3	A complete data set for OTA and grape, with appropriate mathematical models describing the temperature/duration relation to toxin quantity, gene transcription and fungal developments (measured as genome equivalents) to be used for risk scenario description.	Achived	FEM	100
2	T5	D3	A protocol for high-throughput Aspergillus carbonarius contamination of grapes and OTA risk estimation”	Achieved. Lamp-based method for screening	ETH	100
2	T6	D2-	One peer reviewed article on dependency of agro-ecological quality	Achieved,	FEM	100

		D3	(described as biodiversity and biocontrol ability) on climatic conditions			
2	T6	D2-D3	one peer reviewed article on Biocontrol index for comparing functional activity of phylloplane microbial communities	Storari phyllosphere paper under preparation	FEM	90
3	T2	D3	List of pest and pathogens reported on the selected alternative crops and available models for spatial and temporal dynamics of pests/pathogens on alternative crops from literature	Achieved	ARO	100
3	T2	D3	List of effective control measures and known biocontrol agents/hyperparasites of pests/pathogens of grapevine, apples, berries	Achieved	FEM ARO	100
3	T3	D1-D3	Adapted P/P physiological models to be used in the ENVIRO tool	Achieved	FEM	100
3	T3	D2	Identification of economically important P/P present in Trentino or potentially immigrating to Trentino – Drosophila suzukii (arrived), Bactroceras, Monilinia fructicola, Alternaria mali	Achieved	FEM	100
3	T4	D3	Prototype tested and 1 scientific publication together with Activity 1	Achieved, Caffarra et al.,	ALL	100
3	T5	D3	At least 2 (instead of 6) implemented models for poorly investigated P/P but potentially becoming epidemic in Trentino – Rosellinia necator, Phomopsis mali,	Achieved	FEM	100
3	T5	D3	Minimum of one peer reviewed article on biology or epidemiology of P/P	Achieved, Review su Drosophila	FEM	100
3	T6	D2	Two peer reviewed articles: Identify the parameters that play a role in the model systems for studying the effect of multitrophic interaction	Pertot et al. to be submitted	FEM	80
				Pertot et al. submitted	FEM	90
3	T6	D2	Two peer reviewed articles on the effect of relevant parameters on the interactions of the multitrophic systems, (ARO, FEM).	Achieved Pellegrini et al.	FEM	100
				Achieved Pellegrini et al.	FEM	100
3	T7	D3	One peer reviewed article on comparison of the model systems in two natural environments, how can climate influence tritrophic interactions (current alpine environment, S. Michele, and Mediterranean climate, Tel Aviv)	In preparation, Pertot et al.	FEM	80
4	A4	D3	Means to suppress P/P that are intensified with climate change	Achieved – *Lysobacter capsici PG4*, *Bacillus amyloliquefaciens* (FEM)	FEM ARO	100
4	T1	D3	Alternative agricultural systems	Achieved	ARO	100
4	T1	D3	At least two peer reviewed articles on environmentally sound means to suppress P/P	Achieved Elad et al.	ARO	100
				Achieved Borenshtein et al.	ARO	100

4	T2	D3	Scale up of prototypes, products	Achieved - 1 product (SCNB2), 1 prototype (Sentinella)	FEM	100
4	T3	D3	Prototype of a web-based platform for managing P/P control and quality under climate change; user evaluation	Achieved – Monberry Decision support system	FEM	100
4	T4	D3	Technologies that could be implemented as adaptation tools in the long term scenario, with cost/benefit and acceptance analysis	Achieved	FEM, ARO, ETH	100
5	T1	D3	new Data Base which integrates all the interesting data (spatial coordinates, meteorological variables, structural and economic data).	Achieved	UNITN	100
5	T2	D2	one peer reviewed article on the effect of climate on economic performance of homogeneous groups of farms.	De Salvo et al. accepted with minor revision	UNITN	95
5	T2	D2	the list on the most important variables influencing the economic performance of Trentino' farms.	Achieved	UNITN	100
5	T3	D3	one peer reviewed article on Analysis of farmers' perception of climate change and one peer reviewed article on willingness to adopt different mitigating/adapting strategies	Achieved, Menapace et al.	UNITN	100
5	T3	D3	several bio-economic farm models for different groups of farms	Not feasible	UNITN	0
5	T4	D3	one peer reviewed article on Modelling farmers' behaviour in response to risk and uncertainty associated to climate change.	Menapace et al., submitted	UNITN	90
5	T5	D3	one peer reviewed article on the sustainability of different strategies.	Rizio et al. under preparation	UNITN	80
5	T6	D3	two peer reviewed articles, one on the results in terms of the willingness to accept or to support the different adaptation strategies, the other on the methodological issues related with the design of the choice experiment.	Achieved, Moser et al.	UNITN	100
				Achieved Cerroni et al.	UNITN	100
5	T7	D3	a peer reviewed article on the study of the potential crops that could substitute existing crop in case of extreme event and peer reviewed article on the analysis of the future impact of these new alternatives.	Paper under preparation (DEXiPM)	FEM UNITN	70

Describe the role of external collaborations or partners and external resources allocated

FBK

FBK has taken advantages of extrenal resources that have been used to study new tools for scientific computing to better implement envirochange models optimizing the software for EM models in the ENVIRO WPS server. FBK started also to study together with external collaborations from local wine makers new scientific approaches to analyze quality indicators and time series, focusing on the influence of climate data on wine quality.

FEM

FEM collaborated with A. Cossu from University of Sassari (Italy) for the model development, with T. Kuflik from University of Haifa (Israel) for the development of web-based DSS, with D. Molitor from Centre de Recherche Public - Gabriel Lippmann (Luxemburg) for an application of phenological models under Luxemburgish conditions, and with V. Simeone form IAM Bari (Italy) for field trials on powdery and downy mildew of grape and *D. suzukii*.

UNITN

During the fourth year we needed to involve some external collaborators. Some of them had a pure support role: Roberto Caparbi for the dataset from the Choice Experiments, Jacquelyn Gui Scarpa for English proof-reading, Inea for data provision. Other collaborations were considered an opportunity to interact with scholars involved in the same field of research (Greg Colson from the University of Georgia (USA), Carlo Fezzi from the University of East Anglia).

The statistical downscaling of climate models was partially carried out by ARPA Emilia – Romagna (Bologna), based on a free agreement.

Collaboration within the consortium

The partners in the consortium strongly interacted during the entire duration of the project. Researchers, Post-doc and PhD students had the opportunity to carry out part of the activities in other labs especially to acquire new skills. The Hosting institutions gave all the necessary facilities to run the trials.

A strong collaboration among Partners is established and it will most probably continue after the end of the project.

3. Conclusions (only forth year)

FBK

The ENVIRO tool represents a state of the art WebGIS prototype created to improve availability and accessibility to climate data and climate change scenarios and an effective web processing framework for scientific computing able to map the impact of climate change on agricultural systems at a compatible scale for environmental studies and policy decision. ENVIRO is a first step on the path to follow to come out of the modeling black box paradigm. What is still missing is a real direct web scripting interaction between the user, the database and the geoprocessing libraries. This is due to a missing framework for online interactive geoprocessing scripting able to control the accessibility of new and implemented goeprocesses on the server. Moreover to harmonize climate data and climate models with local geographic data using different sources the multiscale factor needs to be mastered. It is a major problem if considering that climate data not only change in space but also in time. The scientific and decision making community need a framework able to resample use full data at the correct scale in space and time using different geospatial approaches and input depending on the application field and data. Real 3D spatial (x,y,z) data visualization, modeling and geoprocessing via Internet in also a major issue that came along while developing ENVIRO. A real 3D web framework able to model, manage and analise 3D spatial data is also something that need further studies. A real 3D spatial analysis library for spatial geodata is still missing.

ETH

ETH max 3000 characters Our evaluation of the proposed molecular identification of OTA mycotoxin producing fungi, lead us to develop a new technology which is more cost efficient, easy to apply in standard viticulture labs. Using with an appropriate sampling strategy the risk of OTA contamination of wines through the appearance of OTA producing Aspergilli (and other fungi) in the Trentino vineyards can be monitored. If the current situation is not yet preoccupying as no risk is present, the use of the acquired data in the scenario of a local increase of temperature (see above) indicates that at lower altitude a risk situation will develop. Contrary there appears to be a positive effect of increasing temperatures on the scab situation: ontogenic resistance of leaves will increase faster than the colonization of apple leaves by the fungus Venturia inaequalis. However we demonstrated this effect only for an increase of linear temperatures of 5 °C. It is therefore dubious if a relevant effect on the situation of scab ant its control is given by the prospected temperature increase of 2-3 °C in the next 50 years. Genes putatively involved in the ontogenic resistance were identified however their direct use (breeding or cisgenesis) is still fare. Next step should prove their role by appropriate experiment such as partially silencing (iRNA) or screening for quantitative segregation in apple progenies or using the apple genome made available by FEM to screen for molecular variability within the respective gene/allele families.

FEM max 3000 characters

ARO

We developed innovative crop protection adaptation tools, effective against pathogens. These include a BCAs and biochar. They are effective against plant diseases and in the present research we showed mechanisms of induced resistance. Genes operated in tomato and strawberry were characterized and a priming effect was found. Biochar was found not only as a mitigation tool but also as an adaptation tool that assists plants with growth and promotes their health (also in bean and cucumber). Not only basic induced resistance was shown but also priming of the plants is activated so they are in a state of alert to face a coming pathogen infection.

UNITN

The analysis of the relationship between economic results of Trentino farms and climate related has demonstrated the possibility to apply the Ricardian approach at a very small geographic scale accounting on data that are easy accessible for all the European regions (Farm Accountancy Data Network FADN, the European Soil Database ESDB). As critical points we highlight that our analysis considers only irrigated farms and the impacts of the expected reduction in summer precipitation can result underestimated. Moreover, since the Ricardian approach is not apt to identify the adaptation strategies the farmers will follow, we are not able to predict if the agricultural sector in Trentino is likely to change in the midterm because of variety and/or crop

switching or shift of cultivations towards higher altitude. Our results are site-specific and cannot be generalized to other contexts.
Overall, the empirical evidence on farmer climate change risk perceptions provides both a positive and negative outlook for policy makers and outreach professionals to assist farmers adapt to changing agronomic conditions due to climate change. On the positive side, we find that a significant portion of farmers in our sample are not merely concerned about climate change, but are indeed forecasting increased crop damage likelihoods for the future. Moving forward with farmer assistance programs, this indicates that the largest hurdle is not educating farmers of climate change induced increases in agronomic risk probabilities, but in assisting with cost-effective methods to control or mitigate these risks. However, our empirical evidence also indicates that farmers' future beliefs are anchored by historical outcomes and personal experience. This feature, which is consistent with heuristic behavior found in many uncertain settings, poses a challenge for farmer assistance programs because it dampens the responsiveness of farmers to evolving crop risks. The survey on farmers results in several important methodological contributions. From an experimental point of view, we show the importance of the framing of gamble task experiment to elicit risk aversion in a context that is closed to the actual risky decisions (for example weather insurance purchase decisions). As a critical point, we emphasize the need to check for the validity of this result with a more diverse sample in terms of farm and farmer characteristics and different crops. From an empirical point of view, we show the applicability of subjective beliefs to obtain more accurate and reliable estimate of risk aversion. A critical point in this context is the need to check the consistency across time and farmers of the subjective beliefs elicitation mechanism. The survey on experts' climate change perceptions was pure qualitative and no statistical analysis was possible because the small number of observations. The application of DExipm tool has highlighted the possibility to use this tool for sustainability assessment of adaptation strategies. However two limits emerged: the need to collect large amount of data and the ability of common users to manage those data. These aspects limit the possibility to extend the application of Dexipm as a decision support tool for single farmers. Moreover the application of Dexipm on a single enterprise raises the issue of not being representative of the general situation. On the other hand, the idea to apply the Dexipm to a representative sample of farms is not feasible because the two limits highlighted above. The only feasible solution appears to collect data for few farms considered representative of different types of farms. The CE on pesticides risk perception is the first stated-preference study which incorporates subjective risks into the design of choice experiment. A limitation of this studies is that the composition of our treatments were subjects face risk levels that differ from their expectations depends on their risk priors. Unfortunately, this procedure may have affected the composition of these subsamples which, in this study, should be similar across treatment groups, as key socioeconomic variables likely affect willingness to pay for R&D programs. Fortunately, having data on these variables allows control via additional econometric modeling.

i) con riferimento al punto i) focalizzare il ruolo dai singoli partecipanti;

4. Validation of results 01/09/2011 to 31/08/2012:

i) Pubblications on scientific journals (only the ones published from 01/09/2011 to 31/08/2012))[1]

Barla A., Jurman G., Visintainer R., Squillario M., Filosi M., Riccadonna S., Furlanello C. (2012) A Machine Learning Pipeline for Discriminant Pathways Identification. Springer LNCS LNBI 7548.

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Jurman G., Riccadonna S., Visintainer R., Furlanello C. (2012) Algebraic Comparison of Partial Lists in Bioinformatics Plos One 7(5): e36540

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[1] Si rammenta che vanno inserire solo le pubblicazioni in cui si faccia esplicito riferimento al finanziamento della Provincia

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A Caffarra, M Rinaldi, E Eccel, I Pertot (2012) Cambiamento climatico e tignoletta della vite: come cambierà l'interazione pianta parassita in Trentino? Extended Abstracts del XV Convegno Nazionale di Agrometeorologia, Palermo, 5-7 giugno 2012:39-40.

Di Piazza, E. Cordano, R. Tomozeiu, E. Eccel (2012) Un generatore sintetico per l'analisi delle proiezioni future di temperatura giornaliera: applicazione ad indici agroclimatici. Extended Abstracts del XV Convegno Nazionale di Agrometeorologia, Palermo, 5-7 giugno 2012:105-106

iv) Scientific collaborations active in the subject of the project/Collaborazioni scientifiche attivate nell'ambito del progetto (locali, nazionali, internazionali)

Project Title, acronym, role (indicate if L, N or I)

CLITRE.50 (L, climate processing of 50-year series in Trentino) – exp. May 2012

CLITRE.100 (L, climate processing of secular series in Trentino, climate projections. In collaboration with ARPA Emilia – Romagna, Bologna) exp. June 2013

v) Patents

vi) Partecipation to projects not funded by PAT on similar subjects

Project Title, acronym, role (indicate if L, N or I)

vii) New equipement, database, exprimental set up methods, etc

viii) Results and products (quantifiable)

ix) Other/Altro

Software packages

R-libraries publicly available in R-Cran repository:

1. Cordano, E., and Eccel, E. (2011) RMAWGEN: Simulations of future weather scenarios with a stochastic Monte-Carlo generator (http://cran.rproject.org/web/packages/RMAWGEN/)
2. E. Eccel and E. Cordano (2912) Interpol.T: hourly interpolation of daily minimum and maximum temperature series. Available on R-cran http://cran.r-project.org

5. Education and courses

UNITN

In the fourth year of the project there was no place for participation of young researchers to new education initiatives. However, leading the implementation of research activities can be considered the best training for young researchers. For what concerns UNITN, Luisa Menapace lead the research activities of task 3 and 4, and Simone Cerroni lead task 6. Before leaving the UNITN research group, Riccarda Moser contributed to task 5.

Roberta Raffaelli and Sandra Notaro, as principal investigator and senior researcher respectively, took part to the INTERNATIONAL WORKSHOP ON RECENT TRENDS IN NON MARKET VALUATION held in Venice 03-04/11/2011 in order to capture the latest advances in choice experiment design and data elaboration to use in the final version of the Choice Experiment on pesticide residue.

FEM

Name Surname	**Where and when**	**Activity**	**Partner**
Emanuele Cordano	EGU General Assembly 2012, Vienna, 22-27 April	Participation with poster	Emanuele Cordano
Amelia Caffarra	EGU General Assembly 2012, Vienna, 22-27 April	Participation with poster	Amelia Caffarra

6. Valorization of results

FBK

A live demonstration to present ENVIRO was given during the closing press conference of the project closing scheduled in FEM on 4th October 2011in San Michele All'adige. A technical meeting was organized in FBK on the 11th of February to present ENVIRO to the local stackeholders as provincial agencies and grower associations

FEM

The products and tools developed in activity 4 are all under commercial development with companies or included in new project (as EU KBBE PURE and CoFREE or EU IAPP INNOVA)

Project ENVIROCHANGE set up the basis for the eventual processing of series carried out in the PAT funded project CLITRE.50 and the EU project IAPP INNOVA.

ARO

Biochar is currently under development with growers

7. Dissemination

Main diffusion and dissemination was through scientific publication and to a lesser extent at Workshops and Congresses.

Dissemination for the wide public worldwide
A final e-conference presenting the major project results was prepared and it is available on the project website (www.envirochange.eu).

A list of bookets to be used by students and wide public have been published on the website

1. Enviro: a platform to map and study the effects of climate change on agriculture at very high resolution Riccardo De Filippi
2. Climate change and agriculture Emanuele Eccel
3. Climate change impact on plant pathogens and plant disease Ilaria Pertot and Yigal Elad
4. Climate change and plant pathogens. The case of two grapevine diseases Amelia Caffarra
5. Genomics to plant health: Effect of climate change on plant Michele Perazzolli , Maria Cristina Palmieri, Benedetta Roatti, Gerardo Puopolo, and Ilaria Pertot
6. Climate change and the risk of ochratoxin contamination – Present and future of Black Aspergilli in Trentino grapes Michelangelo Storari
7. Climate change and ontogenic resistance Michele Gusberti
8. *Drosophila suzukii*: a new invasive species threatening European fruit production Gianfranco Anfora
9. *Rosellinia necatrix*: an increasing problem in replanting of apple orchards Sandro Pastorelli
10. Alternative tools in agriculture Dario Angeli, Alberto Pellegrini, and Oscar Giovannini
11. Climate change and possible impacts on soil Paola Elisa Corneo, Noemi Herrero Asensio, Claudia Longa, Alberto Pellegrini, Michele Perazzolli, and Ilaria Pertot
12. The biochar effect: plant resistance to biotic stress Yigal Elad and Ellen Graber
13. How many bad apples are in a bunch? An experimental investigation of perceived pesticide residue risks Simone Cerroni, Sandra Notaro and W. Douglass Shaw
14. Risk aversion, subjective beliefs, cognitive heuristics and farmers' perceptions of risks related to climate change Luisa Menapace, Gregory Colson, Roberta Raffaelli

Other activities related to the topic of the project

Date	Site	Description
18/01/12	Trento	Liceo G. Prati, Trento: lesson “Climate change in Trentino: where are we now?”
23/02/12	S. Michele	Agrarian School pole: lesson for V and VI year students: "Climate change and the impacts on viticulture"

The dissemination of research results of UNITN was carried out by submitting research papers to some of the most important conferences in the field of agricultural and environmental economics. Papers successfully overcome the strict peer revision process and were presented to the annual conference of the European Association of Environmental and Resources Economists in Prague, to the annual conference of the Annual Meeting of the Agricultural & Applied Economics Association and finally to the triennial conference of International Association of Agricultural Economist in Foz de Iguazu (Brasil).

8. Costs

Describe the major costs for each participant/descrivere brevemente i costi più rilevanti per singolo partecipante.

FBK
The major cost for FEM is related to personnel costs
ETH
The major cost for ETH was salaries. With the conversion rate Euro to swissfrancs with the Euro drastically devaluated compared to the Swissfranc the money available for salaries was cleary less than anticipated. Similarly also the cost for consumables was well above the estimated cost, however we were able to compensate with our ETH-budget. A high cost was created by the change of sequencing strategy which we adopted do to the development of whole transcriptome sequencing technology, however this could be covered by the position unforeseen which to which we had allocated 5% of the total budget.
FEM
The major cost for FEM is related to personnel costs
ARO
The main costs were personnel (technician, Ph D researcher and students) and consumables.
UNITN
The major costs for UNITN in the fourth year are related to the personnel involved in the research activities. Since young researchers for different reasons could contribute only part time to the project, a lot of operative research has been done also by the principal investigator (Roberta Raffaelli) and by the senior researcher (Sandra Notaro). Other relevant costs are payments for external collaborators as explained above, and the cost for the choice experiments administration on a sample of 797 Trentino taxpayers.

SEZIONE 3: Final scientific report

1. Summary of activities

FEM

FEM scientifically and financially coordinated the project. The activities in FEM were mainly focused in developing the models (plant phenology, pests and pathogens), validating them, preparing the scripts for the inclusion in ENVIRO and the analysis of the results. All the potential pest and pathogens affecting the major crops in Trentino have been considered and the available information was collected in a database. Some study cases have been selected on grapevine and apple based on the potential risk of being affected by future climate changes. Protected crops as berries seems not to be affected by climate change. On grapevine we evaluated the risk of powdery mildew and *Lobesia botrana* taking in to consideration the susceptible stage of the plant. On apple we considered the risk of Fireblight outbreak on the susceptible stage (bloom). On grapevine the variation in the number of treatments under climate change conditions on grapevine has also been evaluated. A new pest (*Drosophila suzukii*) and two pathogens (*Phomopsis viticola* and *Rosellinia necatrix*) have been identified as potential new threats in Trentino. The environmental condition suitable for their development have been identified. The effect of climat change have been evaluated on systemic induced resistance and the progamic phase on apple and strawberry. Specific multitrophic systems have been studied: grapevine/powdery and downy mildew/B52 and Y13, zucchini/powdery mildew/*B. amyloliquefaciens*, bean/*B. cinerea*/*B. amyloliquefaciens*, tomato/grey mould/*B. amyloliquefaciens*, soil/ natural microflora/weeds, soil/*Armillaria mellea*/*Trichoderma atroviride*, grapevine/*Lysobacter capsici* PG4/natural microflora have been studied. On all systems climate change is forecasted to have an impact both on plant, pathogens and biocontrolagest/microflora. Several tools have been identified to cope with the effect of climate change on pest and pathogens: in particular biofungicides and resistance inducers. Biofungicides and formulations have been scaled up to medium volumes and successfully tested under field or greenhouse conditions. Web-based DSSs have been developed to manage plant protection on grapevine and strawberry. The system on strawberry is built as a platform that can be further implemented with other crops. In conclusion the activity of FEM in collaboration with the other partners answered to the main questions of the project: what will be the entity of climate change in Trentino? What are the major changes in term of pest and pathogen risk in a view of climate change? What are the interaction in the agroecosystems among plant, pathogens and beneficials? What we can do to counteract the effect of climate change on pest and pathogens? What can be environmentally and economically sustainable?

FBK

The principal FBK activity within the EnviroChange project consisted in the development of ENVIRO, an innovative WebGIS platform for data integration and modeling in applied climate change research. With ENVIRO, scientists from different disciplinary sectors can integrate environmental, agricultural and socio-economic data; ENVIRO was designed to support the entire pipeline of implementation, validation of experimental models, based on high resolution climate data from the past andfuture regional climate change scenarios. ENVIRO was developed by using an open source software -- open data approach. Most of data were obtained by harmonizing a large collection of spatial datasets from public data, in particular by deriving high resolution maps from meteorological data. To integrate novel and existing data, a system of geographical web-services and an interface to spatial data catalogues was developed. The platform also includes rich metadata management features to provide clear indications on quality and provenance of data. All technical components of the ENVIRO platform are based on the most recent generation of Open Source Software for geospatial data endorsed by the Open Source Geospatial Foundation (OSGeo). During the preparation of ENVIRO, FBK also supported digitalization and mapping of new georeferenced data regarding environment and agriculture production, including socio-economic time-series, as needed in the project. Further, FBK contributed to the efficient implementation as ENVIRO web-services of several climate-dependent plant-pathogen models originally designed by FEM experts.

The models were re-implemented from R to Python and tested in a distributed computing environment both on the FBK Kore cluster as well as on the Amazon Elastic Cloud computing system. Also in collaboration with FEM, FBK developed experimental agent-based models, at leaf unit, of infection diffusion of *Plasmopara viticola* or *Erysiphe necator*, in order to obtain a high resolution space-time analysis. Finally, FBK developed within the EnviroChange project a set of new bioinformatics algorithms for multivariate analysis studies on large datasets addressing the discovery of patterns within time series and the study of functional changes in biological pathways. A computational solution for time series clustering (on high performance GPGPU hardware)was developed for up to 10^4-10^5 time series applied to identify classes of vineyard maturation as a function of sun radiation and temperature. For biological networks, the impact of enrichment variability in pathways profiling was studied, and a method for reverse engineering of functional pathways by using Artificial Neural Networks was applied to *Drosophila melanogaster* developmental gene expression data. New methods were explored to obtain the association between features in complex databases in order to extract patterns of non-linear relationships between environmental and climatic features with functional response in plant-pathology systems. Overall, FBK aimed at creating an interactive data analysis environment which interfaces research models with geographical information, experimental data, and climate scenarios. The major challenge was to provide an user-friendly and versatile WebGIS solution for geospatial data processing and visualization both for researchers and decision makers. The ENVIRO platform has been completely developed as a modular client server architecture. The implementation follows international standards developed by the Open Geospatial Consortium (OGC) for geodata transmission and geoprocesses to ensure a complete interoperability with existing and future spatial data infrastructures (SDIs) for climate change studies. The backbone of the system is a spatial temporal database for vector and raster data which addresses the main objective to harmonize together and give access to regional and continental time series of weather/climate data, climate and climate change scenarios, land use geodata and general administrative and statistical data. In terms of scientific analysis, ENVIRO enables researchers to pursue the implementation of new models, as well as access already implemented environmental models able to simulate life cycles of plants and pathogens and their interaction. To sustain the requests for on line geoprocessing of large environmental models on climatic data, the ENVIRO scientific computing environment has successfully used high performance computing methods (GPGPU and Cloud Computing). In summary, ENVIRO is possibly one of the most complex existing ICT platforms for applied climate-change studies with a focus on modeling effects on agriculture at high resolution, in space and time. Within the project, a set of models for simulating the impact of climate change on plant-pathology systems has been developed and efficiently implemented in ENVIRO. The ENVIRO system has been regularly delivered, first as prototype and then as complete system within the project timeline. The system has been presented in a live demonstration in occasion of the closing press conference of the project (4th October 2012, San Michele all'Adige). A presentation technical meeting was organized by the Envirochange consortium in February 2013 (FBK Trento) to introduce ENVIRO to the local stakeholders as farmer associations, experts from wine producers, technical officers from PAT departments.

ETH

The activities include: description of the onset of the ontogenic resistance of apple leaves in relation to temperature. Identification of the gene set which is expressed at the change from susceptibility to resistance and possibly identification of molecular mRNA based marker for this particular phase. Develop local scenario for risk of contamination of wine with mycotoxins based on the temperature driven model of the pathogen development and the production of mycotoxins and deliver a rapid and highly sensitive test to be used in risk areas. Trentino vineyards were surveyed for the presence of black aspergilli shortly before harvest. Despite an abundant presence of black aspergilli in and on berries only a single mycotoxin (OTA) producer was found, which is an indication that currently these genotypes are still largely absent. Genes of the biosynthesis of OTA where identified and used to design specific markers of OTA producing aspergilli. A rapid and cost effective test (LAMP) for

OTA producing aspergilli was developed. Risk of OTA producers presence and consequent wine contamination was analyzed for various climatic conditions through a simulation program, which confirmed for the current conditions "absence of any risk" in Trentino, however suggests with increasing August temperatures an increasing risk beginning in the lower part of the Adige valley. The risk model inserted in the ENVIRO tool combined with the LAMP-test results will allow the operators of the wine producing industry to evaluate risk of mycotoxin contamination and therefore the adoption of precautionary measures. Ontogenic resistance of apple leaves against scab, caused by *Venturia inaequalis* is visible as increasing reduced number of lesion and longer incubation time with the aging of leaves, until complete resistance at end of leaves expansion assuming identical inoculation conditions. As first step we developed a DNA-PCR based methodology to quantify *V. inaequalis* in apple leaves also prior to the visibility of the symptoms. Using this system in combination with visual scoring apple leaves of plant cv Golden Delicious were classified into a range of resistant classes and leaf expansion related age classes at various temperature (15, 20, 25, 29°C). Results from linear modeling the relation between age of leaves and disease development suggest that the ontogenic resistance increases faster at higher temperature than the development of symptoms (and fungus) with the results that scab severity, assuming identical leaf wetness/infection conditions, will lessen with increasing temperatures. After the description of the phenomena we investigated the genomic determinants by whole transcriptomic analysis. A set of genes functionally related to leave growth and plant defence was identified, opening now the possibility for breeders and genetists to search for genetic variants of apples with a high and early expression of ontogenic resistance. On the other hand this work indicates that the expected temperature increase assuming similar rain pattern will not increase scab problems, rather a decrease can be expected.

ARO

As climate is warming up, it is expected that larger areas in Trentino will be exposed to higher temperatures, more sunny days, shorter winter and longer summer. Conditions in the fall and spring will be milder. In some areas it will be possible to grow in the open some field crops or fruit trees that originate from warmer regions and greenhouse crops. A list of suggested crops and current varieties that fit the new climatic scenario was formed, yet with potential pests and diseases. Among the alternative crops are tomato, cucumber, potato, and other highly valuable agricultural plants. Induced disease resistance in plants is a physiological state of enhanced defensive capacity elicited by specific stimuli, whereby the plant's innate defenses are potentiated against subsequent challenges. This enhanced state of resistance is effective against a broad range of pathogens and parasites, including fungi, bacteria, viruses, and nematodes. For adaptation purposes, we studied induced resistance in strawberry plants under the changing environmental conditions that are expected due to global warming. Inducers that are tested in the present study include *Trichoderma harzianum* T39, acibenzolar-S-methyl (BTH, Bion), a new SCNB2 inducer and isolates of a bacterium B52 and a yeast Y13. These agents not only effectively suppressed powdery mildew on leaves when sprayed on the canopy, but also induced systemic resistance when applied to the root zone while disease was evaluated on the leaves. Plant growth was enhanced in the presence of the biological inducers in the root zone, espetially under limitted irrigation conditions. The effect of different temperatures and water stress conditions on induced resistance were studied. The induced resistance agents, that can serve as adaptation agents, had a positive effect on plant growth. However, the plant growth conditions affect the activity of the inducers and ability to induce disease suppression. This is evident with drought and with temperatures. Interestingly, some of the negative effect of a biotic conditions is nullified the inducers. The mode of resistance that is induced by root zone-applied T39 and BTH towards *P. aphanis* was studied in strawberry plants. In this system real-time quantitative PCR was used to examine the effects on expression of defense-related genes in strawberry leaves. One day after the drenching of strawberry roots, T39 and BTH had affected the expression of PR-encoding genes. Grey mould (caused by *Botrytis cinerea*), is a major fungal disease of the alternative crop-tomato world-wide. We aimed at shedding light on defense-related gene expression involved in the induced resistance against *B. cinerea* in tomato plants by the control agents BTH and T39. In whole plants submitted to drenching treatments, transcriptional

changes related to the phytohormones salicylic acid and ethylene were induced by benzothiadiazole, while jasmonic acid related changes were induced by T39. Biochar is the solid co-product of biomass pyrolysis. The biochar can be applied as a soil amendment, where it permanently sequesters carbon from the atmosphere, as well as improves soil tilth. We found that soil-applied biochar induces systemic resistance to the foliar fungal pathogens. Various biochars added to soil have been shown to improve plant performance. biochar stimulated a range of general defense pathways, as confirmed by results of qPCR study of defense-related gene expression. Furthermore, primed-state of defense-related gene expression was observed upon infection by *B. cinerea* and *P. aphanis*.The results from the quantitative disease assay and induction of genes expression strongly suggest that jasmonic acid signaling pathway is important for biochar-mediated resistance to *B. cinerea* in tomato. Generally, it was predicted that diseases of the crops in question will become more severe within time and measures to combat these problems will need to be powerful and intensive. Treatments that were tested in the different plant-pathogen systems included BCAs from our collection or commercially available, friendly control agents (both resistance inducers or biocides). We focused on P/P, which indicate a potential high impact in the selected scenarios of Activity 1, and we developed new environmentally sound control measures and adjusted agronomic practices for the optimization of plant protection and agronomic management. A climate change reflection on the biotic and abiotic stress as well as on the control agents was described. Moreover, we studied the mode of action of the inducers and we could show an adaptation as well as mitigation role in the researched systems.

UNTN

A dataset was assembled containing structural and economic information about the 312 Trentino farms growing apple and grapes in Trentino included in the Farm Accountancy Data Network in period 2003-2007. Climate data were interpolated and associated to each georeferenced farms as long as soil data extrapolated from European soil map databases. On this database we run econometric models to investigate the relationship between profitability and climate related variables. The relationship in the long run, investigated trough a Ricardian approach application, allows us to forecast the effects of climate change on the Trentino agriculture. As a consequence of an expected increase in temperature (+1.4°C) and decrease in precipitation (-6%) we estimate a reduction in annual net revenues which ranges from a minimum of 78.33 €/ha to a maximum of 750.29 €/ha but the overall impact could be underestimated as the more adverse effects on non-irrigated farms are not taken into account. The hill-shaped relationship between farm profitability and average temperature and precipitation is confirmed also by using annual weather data (2003-2007). This analysis highlights the variables that influence current farm profitability in a significant manner. Among others, net revenue per hectare depend heavily also on farmer's age and on the values of variables connected with farmer's strategies such as specialization and quality certification and insurance subscription. To investigate farmers' perceptions of climate change, their degree of risk aversion and their decision behavior in situation of risk and uncertainty we design and administered a two round field survey to 312 farmers. From the surveys with farmers, evidence emerged that the majority of interviewed farmers not only are familiar with the perils due to climate change in general but also display quantitatively detectable perceptions of future hazard (hail and pest risk) to their farming operation that are directly or indirectly related to climate change. We found a statistical significant relationship between risk perceptions and risk attitudes, while this relationship has been neglected in existing studies. Specifically, we find that farmers who are more (less) risk averse tend to perceive greater (smaller) probabilities of farm losses occurring. The experimental component of our study has revealed that only a gamble task defined in terms of farm income is good in predicting farmers insurance purchase decisions. At the expert level, a survey was carried out on a small sample of experts (14 subjects) belonging to the viticulture advisory service of FEM. The survey questionnaire was adapted from Olesen et al. (2010) and tailored to Trentino viticulture. According the interviewed experts climate change is not perceived to impact a great deal on the Trentino agriculture and no big changes in adaptation practices are expected.

The analysis of sustainability of four adaptation strategies (variety switch, crop switch, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones) has been carried out by applying the Dexipm software to data collected for the FEM farm. The Dexipm tool has been integrated with three new indicators. The analysis highlights only small difference in terms of sustainability among the selected adaptation strategies in the specific case study. More interestingly the Dexipm tool emerges as a flexible and suitable tool for assessing sustainability of adaptation strategies at the farm level. For investigating dwellers' preferences for production methods and crop protection strategies that are linked to climate change, two choice experiments were carried out. The first focuses on current purchasing behavior of apple consumers (288 subjects) and the second focuses on taxpayers' willingness to support R&D programs for developing innovative methods to control the spread of new apples diseases due to climate change. The choice experiment on 288 apple consumers revealed that Trentino consumers are currently willing to pay only for organic production method but dislike IPM or IPM using biological control agents extensively. Consumers are willing to pay for mitigation practices that reduce the greenhouse gas emissions. From the Choice Experiment on 797 respondents from the Province of Trento dwellers emerge to expect an increase in the number of apples containing pesticide residues (75 out of 100 in 2030 with a 50% change). The willingness to support pay for R&D programs for developing innovative methods to control the spread of new apples diseases due to climate change depends on the number of apples containing pesticide residues, on risk attitude, time preferences, net annual income, being an apple consumer or producer, and consumer association membership. The marginal WTP for a reduction from 75 to 15 apples containing pesticides in around 1,2 euro per taxpayer per year. From a methodological point of view evidence emerges the risk information provided in the Status Quo alternative strongly affects choice behavior and the WTP for reducing the risk of pesticide residues.

Describe deviations from the original plan/Evidenziare se sono intervenute variazioni rispetto alla proposta iniziale.

FBK

No major deviations.

ARO

Generally the main research dealt with the initial objectives. Dealing with various means to manage diseases and accommodate changes that are expected due to climate change, we were fortunate to start a new subject that can serve as adaptive means and as a mitigation tool – the biochar. Biochar was found not only as a way to capture carbon dioxide but also as a material that promotes soil fertility and as an inducer of disease resistance in plants. Adding research on biochar to the project is a deviation from the original plan. It was not developed anywhere at all when we started the project and thanks to the inclusion of the research on this tool in the project it not only allowed a significant widening of the tools that we studied and promoted but also it is now taken by other research center to further develop systems that rely on biochar.

ETH

Instead of performing the genetic analysis in relation to ontogenic resistance on three cultivars using differential expression of genes we opted for a threefold repeat of a single cultivar. This for a better reliability of the obtained results. Unfortunately, due to the high cost of RNA sequencing it was not possible to have 3 x 3 data sets.

Technical development led us to develop a LAMP test for fungi carrying genes of the biosynthesis for OTA instead of a PCR 96 Platform. The advantage is that a simple thermoblock (constant temperature) is need instead of a cycler, visualization is immediate through a color change in the reagent tube. Cost is much lower and the test is executable in any standard lab.

FEM

In activity 2 it was not possible to obtain a consistent response of the biocontrol index, therefore the activity was modified into the analysis of effect of temperature on soil microflora (by studying an altitude gradient) and the effect of climate on phyllopshere microflora in presence of a biocontrol agent. No other major deviation.

UNITN

The recent applications of the Ricardian approach on European countries (Lang, 2007; Lippert et al., 2009; Fezzi and Bateman, 2010) published in peer reviewed journals and presented in international congress (EAERE Amsterdam June 2009) suggested us to address the issue of Task 2 by using this approach. The necessity to have interpolated climate variables associated to each geo-referenced farm, forced us to restrict the analysis to the Trentino province for which a spatial interpolation algorithm was already available. This lead to a reduction of the sample size and the typology of farms, making multivariate statistical analysis and farms stratification redundant. The final sample containing 312 farms growing apple and wine grapes forced us to focus our analysis on profitability measures instead of crop yield, since the latter is mainly managed by thinning out, except in the case of frost and hail.

The identification of a new approach to elicit and estimate subjective probability distributions, the exchangeability method (EM) (Baillon, 2008), has lead us to employ it extensively in the analysis of both farmers and consumers risk perceptions. The choice of this approach make redundant the original idea to follow the 3 approaches (behavioural/attitudinal questions, interval hypothetical choices, investment choice) suggested by Fausti & Gillespie (2006, Austral. J. Agric. Resour. Econom., 50, 171-188). Compared to what was originally proposed, we managed successfully to expanded the types of risks that we have investigated. In fact, for each type of farmers (apple farmers and winegrowers) we elicited not only risk perceptions of damage by given pests but we also elicited perception of the risk of hail damage. It has not been feasible for us to prepare the survey within the time frame required by Inea to have the survey administered in spring 2009, as originally planned. As the survey had to be administered in spring when farmers had to decide whether or not subscribing an insurance, we could not count on Inea for survey administration but we had to administer it by ourselves. The development of a bio-economic simulation farm model, as planned in the original version of the project, resulted to be unfeasible. A careful review of the literature has indeed revealed the lack of crop models that could have been considered suitable for modeling the perennial crops grown in Trentino (e.g., orchard and vineyards). In addition, the limited time resources available to the project's partners for developing an ad hoc model pushed us to consider an alternative approach. We had to drop the idea to build bio-economic simulation farm model and data collection for addressing task 3 and 4 were integrated into a two round farmers survey. Similarly, the publication of a survey on climate change and adaptation strategies perceptions by experts at the European level (Olesen et al., 2010) suggested the appropriateness to employ a survey instrument to test experts' perceptions at the provincial level. The methodology originally proposed for sustainability assessment requires a huge amount of information to be collected both at the farm and provincial level. Moreover, at the current state of the art most adaptation strategies can be defined only in a broad general way and no data are available. The development of a new flexible tool (Dexipm) starting from the DEXi decision support system (Bohanec, 2009) has provided us with a new tool to evaluate sustainability of adaptation strategies in a qualitative way. So we applied it to a case study farm. The original task of evaluating "the social acceptability of some adaptation strategies" had to be redefined according to the evidence that laypeople mostly concern about their health and the effects of adaptation strategies on the use of pesticides. We had therefore to shift our focus from general adaptation strategies to the crop protection strategies and the R&D which is necessary to face future pest developments. Before starting the final choice experiment on dwellers' behavior towards future situation characterized by risk and uncertainty, we collected information on actual purchasing behavior of consumers towards apples produced with low environmental impact production methods.

2. Report on activities

Activity 1 Assessing the effects of climate change in Trentino agro-ecosystems: the ENVIRO tool

Task 1 Development of an integrated EM/GIS analysis tool for Trentino's major agricultural pests (ENVIRO) (FBK).
Task 2 Construction of weather scenarios under global warming and custom conditions (FEM)
Task 3 Integration of GIS, weather and field data and remote sensing data (FBK, FEM).
Task 4 Prediction of P/P spatial patterns and fruit quality loss under climate change scenarios (FBK, FEM)

The main result of this activity is **ENVIRO**, an intuitive, innovative and customizable EM/GIS-based platform allowing the rapid identification of P/P ecological niches and fruit quality impairments, under current-, custom- or global warming weather scenarios. This prototype system includes adaptability to all worldwide regions where hosts are cultivated, the modeling of P/P relationships on new hosts as well as modeling of any new potential P/P. ENVIRO is a platform that framewoorks Integrated Assesment Models (IAMs) to quantify the environmental risk and the vulnerability of agricultural systems to climate change in Trentino and to study and propose policy options based on climate. The platform is designed for two groups of users: environmental scientists that use weather driven experiments to predict how the plants and pathogens systems react to climate change, and policy makers that are interested into simulate and map the change of political strategies onto two main agricultural products for Trentino as grapevine and apples. The platform is modular, with a typical WebGIS client server architecture. It follows the international standards established by the Open Geospatial Consortium (OGC) for geodata transmission and geoprocesses making it completely interoperable. In the project we used ENVIRO as a scientific basis for research to project the effect of climate change on the most relevant pest and pathogens of grapevine and apple in Trentino. It was also used to estimate the change in the number of treatments against powdery and downy mildew of grape. Details on the tool and applications have been and will be published in scientific peer reviewed journals.
We provided specifications and user evaluation for translating ENVIRO into the standard platform on which the Trentino governmental agencies, farmers and winegrowers cooperatives can develop policies adequate to counterbalance climate change and the design and the managing of sustainable agro-ecosystems. The system will be presented to Provincial agencies, grower associations on the March 6th 2013. The project can also provide specification for its use by schools and professionals as a learning tool in the agronomic sectors.
The activities in Task 2 (Construction of weather scenarios under global warming and custom conditions) have been partially carried out with the contribution of project ACE-SAP, whose climate modelling section has aims in large part coincident with those of ENVIROCHANGE.
Before any processing of weather series, a general task of series merging, gap filling and homogenization was carried out starting from 73 and 52 series of precipitation and temperature, respectively, collected from the province of Trento and the surrounding areas. The tasks were carried out with R open source code RHtestV2, made available via the website of Action COST ES0601 "HOME".
Climatic projections were downscaled for a selected number of high-quality series (10), by a Canonical Correlation Analysis technique (collaboration with Rodica Tomozeiu - ARPA Emilia – Romagna). Outputs from EU Project "Ensembles" were used (7 Glob. Circ. Models, scenario A1B) for the standard "Ensembles" periods 2021-2050 and 2071-2099 (30-year means). A "sub-downscaling" algorithm was used to extend the statistical downscaling to all the remaining ones. A "partial least square regression" approach was used, utilizing the R library "pls". A general DB including all the instrumental series considered in ENVIROCHANGE was built as a compact R object, and the above mentioned R library was created to manage data retrieve from this DB.

Daily projected series have been produced by the application of a “weather generator”, to generate an indefinite number of stochastic series all meeting the given climatic features, coming either from the instrumental climatology (like the “reference period” 1961-1990) or from downscaled projections. The weather generator was built from an autoregressive model having a “multisite” facility. The latter has the important peculiarity of maintaining the statistical correlation among series, thanks to the simultaneous generation of all the series at once, so that series can be applied also for spatial interpolations.
Hourly interpolation was required for two reason. First, it is necessary for many pest infection models; second, because it can adjust systematic errors on the assessment of mean daily temperature from minimum and maximum values alone. The interpolation was carried out with three interpolating functions for each day, according to the algorithm created on purpose.
The availability of relative humidity data has been suggested for use in some pest models. In this project, it is envisaged in a simulation of powdery mildew for grapevine. An algorithm for atmospheric humidity simulation was developed and implemented.
This fundamental pre-processing gave rise to homogenous series, and strongly reduced the scattering of climate trends over the area. This analysis produced an assessment of climate trends over the area in 50 and 30 years, and some interesting features (differences among seasons, elevational patterns). All the series contributed to the DB that was passed for further processing to the ENVIRO platform. A paper was published (see deliverable list WP1, Task 2: 5).
This is the “core” analysis of the Task, which generated the future projections from statistical downscaling of the output of a multi-model ensembles. The “sub-downscaling” procedure allowed to produce two climatic fields of temperature and precipitation, necessary for high-resolution reproduction of climatic projections: the “reference” climatic condition (1961-1990, potentially also a different period); and a downscaled set of predictions (2021-2050 and 2071-2099). These fields refer to the whole set of available sites for this project. A robust statistic, the ensemble median of the seven climatic models, was considered for sub-downscaling and the further analyses. These jobs contributed to some congress communications and to a paper, submitted. Ref. deliverable list WP1, Task 2: 5,11.
The weather generator “RMAWGEN” (R-based Multisite Autoregressive Weather Generator) is an advanced tool publicly available via the R-cran site, since the work was published as an R library. The result of the applications of RMAWGEN are daily series of temperature and precipitation, not independent one from another, as would be if the generation was carried out singularly for any series. The weather generator can generate an indefinite number of realizations for each scenario, from which probabilistic results can be obtained. Ref. deliverable list WP1, Task 2: 6,7,13,14.
The hourly interpolation algorithm was used for two purposes: to generate hourly temperature series (for further modelling, for example for the simulation of atmospheric humidity), and to generate sound daily means, to avoid the systematic bias arising from the averaging of minimum and maximum values. Deliverables included some papers and the publication of an R library. Ref. deliverable list WP1, Task 2: 1,2,12.
The feasibility study highlighted the possibility of using the algorithm. The feasibility study showed that the generation of relative humidity series can be successfully done, if the aim is just the representation of mean values. But if the correct representation of “very humid” hours is the aim, then only some sites are suitable for this kind of simulation. This simulation was applied to the modelling of infections of powdery mildew (ongoing job). Ref. deliverable list WP1, Task 2: 3,4.

Deliverables (see table for additional information)
T3 D2 ENVIRO tool: integration of weather driven physiologically based ecological models with geographical information system and remote sensing.
The main objective of ENVIRO is to give access to regional and continental time series of climate data from the past and future climate change scenarios, together with environmental models for grapevine and apples and their pathogens and Trentino administrative and statistical geodata. In terms of scientific analysis, ENVIRO enables the access to reproducible research tools via already

implemented and well documented environmental models able to simulate life cycles of plants, pathogens and their interaction, in any Trentino's land parcel.
Four elements compose the ENVIRO architecture:

- **enviDB**: the spatial temporal database, where all spatial and thematic data are structured,
- **enviGrid**: the spatial temporal user panel to access the different regional climate databases,
- **enviMapper**: the web interface for decision makers to map vulnerability of agricultural systems to climate change,
- **enviModel**: a web interface and a model repository for researchers. They can process their models and make their results reproducible.

T4 D1 ENVIRO tool: Historical and global warming, temperature and precipitation scenarios were included in ENVIRO.

T5 D3 Visualization of vulnerable host areas, ranges of expansion and climatic limits of P/P, under current and global warming scenarios.
The vulnerable areas have been identified in term of risk of increased risk of P/P and considering the plant phenology and susceptible stages; examples were powdery mildew of grape, *Lobesia botrana*, Fireblight of apples.

T1-T3 D3 Two peer reviewed articles on ENVIRO and its applications.
Eccel, E., Cau, P., and Ranzi, R. (2012) Data reconstruction and homogenization for reducing uncertainties in high-resolution climate analysis in Alpine regions. Theoretical and Applied Climatology, 110(3): 345–358.
Caffarra, A., Rinaldi, M., Eccel, E., Rossi, V., Pertot, I. (2012) Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. Agriculture, Ecosystems and Environment, 148: 89–101.

Activity 2 Assessment of biophysical impacts of climate change on quality and production of crops of Trentino

Task 1 Direct effect of climate change on quality and production indices. Identification of algorithms predicting phenological stages, climate-dependent quality and production indices for crops of interest existing in Trentino (apple, grapevine, strawberries, and other berries and some horticultural crops)(FEM).
Task 2 Genomics to phenology: effect of climate change (ontogenic resistance) (ETH). Description of the onset of ontogenic resistance in apple leaves in relation to temperature. Identification of the gene set which is expressed at the change from susceptibility to resistance and possibly identification of molecular mRNA based marker for this particular phase.
Task 3 Genomics to plant health: effect of climate change on plant self-protection (induced resistance).
Task 4 Indirect effect of climate change on fruit quality. To evaluate if climate change has an effect on pollen performance (pollen tube kinetics and dynamics) considering the genotype-temperature interaction. Flowering is among the most vulnerable development stages to temperature fluctuation and the prevailing temperatures during bloom have an agronomic impact, which can result in poor fruit quality (size) or on fruit set. Evidences for differential interaction T-genotype in the progamic phase in fruit trees is described. (FEM)
Task 5 Indirect effect of climate change on food quality (mycotoxins contamination). To develop local scenario for risk of contamination of wine with mycotoxins based on the temperature driven model of the pathogen development and on the production of mycotoxins. To deliver a rapid and highly sensitive test for detecting the fungus and mycotoxin production in risk areas (FEM, FBK, ETH).
Task 6 Evaluation of agro-ecological quality: biodiversity and biocontrol under climate change (FEM).

The overall activity provided models and concepts to be included in the GIS Tool (ENVIRO) to estimate the impact of climate change. In particular we evaluated the effect of weather parameters on quality of major crops in Trentino in the selected scenarios of climate change. The analysis showed that within the range of climatic changes foreseen in the future decades, quality of apple, grape and strawberry will be not substantially influenced. The major reason is because most of the Trentino surface is irrigated and based on the climatic projection we will not expect a decrease in the total precipitation, but only a different distribution during the season. The phenological model for grapevine (6 varieties, 2 trellis systems), apple (1 variety) and strawberry (1 variety) have been constructed and validated.
One of the main questions was if and to what degree a change in temperature influences the ontogenic resistance and therefore decrease or increase scab severity. Apple scab disease was in the past only assessed visually as incidence (number of plant units with lesions) so we developed a quantitative measure of fungal presence by quantification of fungal DNA in leaves. Young Golden delicious plants were inoculated at different temperatures with the pathogen. Resulting lesions, growth of leaves and quantity of fungal DNA were measured in two independent long time trials under fully controlled conditions. Whole transcriptome was quantitative analyzed by RNA-sec. In three biological repeats old-young, inoculated not inoculated leaves were analyzed at two time points. The data was analyzed in silico and differential expressed genes annotated and analyzed for their potential role in ontogenic resistance. The sequences of the candidate genes were made available for further development of quantitative RNA-based markers. A DNA-PCR based methodology to quantify *V. inaequalis* in apple leaves also prior to the visibility of the symptoms was developed. Using this system in combination with visual scoring apple leaves of plant cv Golden Delicious were classified into a range of resistant classes and leaf expansion related age classes at various temperature (15, 20, 25°C). Results from linear modeling the relation between age of leaves and disease development suggest that the ontogenic resistance increases faster at higher

temperature than the development of symptoms (and fungus) with the results that scab severity, assuming identical leaf wetness/infection conditions, will lessen with increasing temperatures. The genomic determinants of ontogenic resistance were evaluated by whole transcriptomic analysis. A set of genes functionally related to leave growth and plant defense was identified and their potential role in ontogenic resistance discussed.

Another key question was if induced resistance and its genetic mechanism are influenced (increased/decreased, delayed/speeded up). Plants possess defence mechanisms to protect themselves against pathogens, which also include the induction of resistance upon treatment with some compounds or beneficial microorganisms. We previously showed the ability of the beneficial microorganism *Trichoderma harzianum* T39 (T39) to induce grapevine resistance to downy mildew (*Plasmopara viticola*), although the molecular events associated with this process and their relevance under field condition have not yet been elucidated. During this project an integrated approach was used to study global transcriptional and proteomic changes associated with resistance induced by T39 in grapevine leaves. By next generation RNA sequencing (RNA-Seq) approach, more than 14.8 million paired-end reads were obtained for each treatment and 7024 grapevine genes resulted as differentially expressed during resistance activation. Moreover, 800 unique proteins were identified and quantified by high-throughput eight-plex iTRAQ protocol and 218 proteins resulted as significantly changed in abundance during T39-induced resistance. The complex transcriptional and proteomic reprogramming of T39-induced resistance included the direct activation of the microbial recognition machinery after T39 treatment and the enhanced expression of defence-related processes after pathogen inoculation. T39-induced resistance partially inhibited some disease-related processes and specifically activated defence responses after pathogen inoculation. In particular, some defence processes known to be implicated in the reaction of resistant grapevines to downy mildew were partially activated by T39-induced resistance in the susceptible grapevine. Genes and proteins identified in this work are an important source of markers for selecting novel resistance inducers and for the analysis of environmental conditions that might affect induced resistance mechanisms. To evaluate the efficacy of the T39-induced resistance under non-optimal conditions and to study pathogen's infection dynamics of different *P. viticola* isolates we evaluated i) the T39-induced resistance in plants exposed to heat and drought stresses, ii) the T39-induced resistance in different grapevine cultivars and iii) the possible selection mechanisms of different *P. viticola* isolates under different climatic scenarios. We could assess that co-inoculated *P. viticola* isolates competed for the infection of the host, although being equally infective when singularly inoculated regardless of the climatic conditions. Competition was not related to the origin of the isolate and we hypothesized that competitive selection was modulated by differences in the secretion of effector molecules, which explained the establishment of dominant genotypes over an epidemic season. We demonstrated that T39-induced resistance was found to be reduced in plants exposed to the combination of heat and drought stresses, moreover, variable levels of efficacy were observed in different grapevine cultivars. Modulation of the marker genes in the T39-induced resistance was partially attenuated in plants under heat and drought stress. The molecular mechanisms activated in response to the resistance inducer were different and complex among cultivars, indicating that specific receptors are probably involved in the regulation of the plant response. Different *P. viticola* genotypes reacted differently when co-existing on a unique substrate, indicating that plant-pathogen interactions seem to be more complex than mere colonization of the plant tissue. The environmental conditions and the plant genotype are key factors affecting the T39-induced resistance.

We attempt to define if pollination of apples (main varieties and their pollinating varieties) and strawberries (main varieties) will be influenced by temperature increase. Closed flowers of two apple varieties (Golden delicious and Renetta) and a strawberry variety (Elsanta) were collected in the morning and let open at 20°C. Pollen was collected and placed on glass slides at 5, 10, 20 and 30°C. Pollen germination was viewed under a compound light microscope. Pollen was considered germinated when the pollen tube was one and a half to twice the length of the pollen granule. 5 and 30°C were detrimental for pollen viability, which was reduced by 50% in average.

The risk of production and contamination of the must by OTA under existing and changing temperatures may increase. A method for fast preharvest analysis in risk zones may be extremely useful. We collected grape berries in 42 vineyards of Trentino and subsequent isolated and identified species and subspecies by DNA sequences black aspergilli. The isolates were characterized by screening all collected aspergilli for the capacity to produce OTA mycotoxin on various substrate and verification of the presence/absence of genes related to the biosynthesis of OTA. We implemented the program "Batalani" for risk of OTA contamination in wines in ENVIRO-tool and Program. Through it we obtained the description of risk OTA contamination of wines scenario for previewed temperature increase scenarios. We developed of a fast cost efficient test for the presence of the OTA biosynthesis genes in black aspergilli and verified the reliability of the developed LAMP-test. Despite an abundant presence of black aspergilli in and on berries shortly before harvest in all surveyed vineyards of Trentino only a single mycotoxin (OTA) producer was found, which is an indication that currently these types are still largely absent. Isolates were characterized as OTA producers and not producers by presence of the OTA biosynthesis genes and the presence of OTA on/in the culture media. Specific markers of OTA producing aspergilli were derived from the genes of the OTA biosynthesis. A rapid and cost effective test (LAMP) for OTA producing aspergilli was developed. Risk of OTA producers presence and consequent wine contamination was analyzed for various climatic conditions through a simulation program, which confirmed for the current conditions absence of any risk, however suggests with increasing August temperatures an increasing risk beginning in the lower part of the Adige valley. The risk model inserted in the ENVIRO tool combined with the LAMP-test results will allow the operators of the wine producing industry to evaluate risk of mycotoxin contamination and therefore the adoption of precautionary measures.

After several unsuccessful trials on standardizing a biocontrol index we adopted a differ approach on soil and phyllosphere. To evaluate the effect of temperature on soil microflora we analyzed microbial communities living in nine vineyards distributed over three altitudinal transects over two years. Fungal and bacterial community dynamics were explored using automated ribosomal intergenic spacer analysis (ARISA) and by determining bacterial cells and fungal colony-forming units (CFUs). Moreover extensive chemical and physical analyses of the soils were carried out. Multivariate analyses demonstrated that bacterial and fungal communities are affected by altitude, which acts as a complex physicochemical gradient. In fact, soil moisture, Al, Mg, Mn and clay content are changing with altitude and influencing the bacterial genetic structure, while in the case of fungi, soil moisture, B and clay content are found to be the main drivers of the community. Qualitative ARISA revealed the presence of a stable core microbiome of operational taxonomic units (OTUs) within each transect, which ranged between 57 and 68% of total OTUs in the case of fungi and between 63 and 72% for bacteria. No seasonal effect on the composition of microbial communities was found, demonstrating that bacterial and fungal communities in vineyards are mostly stable over the considered seasons. To assess the effect of climate on the phylloplane microflora and on its biocontrol ability in defence of the plant, we artificially inoculated a biocontrol agents (*Lysobacter capsici*) on grapevine under two different environmental conditions having an average difference in temperature of approximately 2°C over the season (Udine and S. Michele all'Adige) and controlled conditions in greenhouse in July 2012. Leaves were washed and DNA extracted and sequenced with NGS. The data indicate that the biocontrol agent is strongly influenced by environmental conditions, and the efficacy is higher when conditions are close to its optimum. The phyllophere bacteria are strongly influenced by the biocontrol agent under its optimal conditions.

Deliverables (see table for additional information)

T1 D1: Database of suitable existing quality and production indices for grapevine, apples, strawberries and algorithms to forecast quality and production based on climate (FEM). The DB was created for grapevine and apple.

T1 D2: Identification for each crop of the quality parameters most likely influenced by climate change. (FEM).
The quality parameters most likely influenced by climate change are soluble solids (°Brix), pH and acid content in grape, soluble solids dor apple and strawberry.

T1 D3: Effect of temperature gradient on fruit quality under climate change scenarios (FEM).
No gradient effect is foreseen under climate change scenarios in Trentino.

T2 D3: A peer reviewed article describing the phenology and genomics of ontogenic resistance in relation to temperature (ETH).
Gusberti, M., Patocchi, A., Gessler, C., and Broggini, G. A. L. (2012) Quantification of *Venturia inaequalis* growth in Malus × domestica with quantitative real-time polymerase chain reaction. Plant Dis, 96: 1791–1797.

T2 D3: Linear model describing the development of the ontogenic resistance of leaves in relation to temperature (ETH).
The linear mixed model (performed using JMP v. 8 on windows vista (see also web site envirochange documents)
A linear mixed model for repeated measures was used to assess the effect of time, temperature, leaf position, treatment, and experiment on leaf's relative growth rate using the Restricted Maximum Likelihood (REML) estimation method. The square root transformation of RGR values was used to reach normal distribution of residuals and equal variance across groups. Data below 0.00001 RGR were excluded from the analysis to avoid excessive zeroes in the dataset. Leaf position, time points, temperature, treatment (inoculated and not inoculated plants), experiment (one and three years-old plants), and interaction of temperature*leaf position where considered as fixed factors. Leaf position nested within subject (shoot) was considered as random factor.

Effects	**DF_n**	**DF_d**	***F-ratio***	***P>F***
Leaf position	4	267.4	114.855	<.0001
Dpi	7	1800	558.495	<.00005
Temperature	4	328.9	16.982	<.0001
Treatment	1	320.6	42.555	<.0001
Experiment	1	397.6	22.033	<.0001
Temperature x Leaf position	16	318	1.473	0.1076

DF_n: Degree of Freedom numerator defined as number of groups analyzed minus 1.
DF_d: Degree of Freedom denominator defined as the number of subject observed minus the number of groups

REML Variance Component Estimates

Random Effect	**Var Ratio**	**Var Component**	**Std Error**	**95% Lower**	**95% Upper**	**Pct of Total**
SHOOT(ID)[LEAF POSITION]	-0.016206	-0.000069	5.6573e-5	-0.00018	4.1787e-5	-1.647
Residual		0.0042636	0.0001455	0.0039922	0.0045638	101.647
Total		0.0041945				100.000

-2 LogLikelihood = -5193.449858
(for model calculation: see ETH PhD thesis Gusberti no. 20883)

T3 D3: A peer reviewed article describing the dynamics of the induced resistance mechanism and its genomics in relation to temperature and drought stress (FEM).
Roatti B., Perazzolli M., Gessler C., Pertot I. Abiotic stresses affect *Trichoderma harzianum* T39-induced resistance to downy mildew in grapevine. Under review in Phytopathology: submitted February 11th 2013.

T4 D2: A peer reviewed article on genotype-temperature interaction in the progamic phase in apples and strawberries (FEM).

Pertot I. Ress D. Climate change will not impact the progamic phase in apples and strawberries. In preparation. To be submitted to Journal of Botany.

T5 D3: One peer reviewed and one technical article describing the effect of temperature on presence and expression of OTA biosynthesis genes and OTA production by local strains under different temperature and duration of incubation (lead ETH participation FEM).
Storari M., Pertot I., Gessler C., & Broggini G.A.L. (2010) Amplification of polyketide synthase gene fragments in ochratoxigenic and nonochratoxigenic black aspergilli in grapevine. Phytopathol Mediterr, 49: 393−405.
Storari Michelangelo, Broggini G.A.L., Bigler L., Cordano E., Eccel E., De Filippi R, Gessler C. & Pertot I. ((2012) Risk assessment of the occurrence of black aspergilla on grapes grown in an alpine region under a climate change scenario. Eur J Plant Pathol, 134: 631–645.

T5 D3: One peer reviewed and one technical article describing the automated system of Ochratoxin risk identification through the RT-PCR and its validation (lead ETH participation FEM).
Storari M., Rudolf R., Gessler C., Pertot I., & Broggini G.A.L. (2013) Detection of ochratoxin A-producing Aspergillus carbonarius and A. niger from grape using the loop-mediated isothermal amplification (LAMP) reaction. Journal of applied microbiology, DOI: 10.1111/jam.12139.

T5 D3: A complete data set for OTA and grape, with appropriate mathematical models describing the temperature/duration relation to toxin quantity, gene transcription and fungal developments (measured as genome equivalents) to be used for risk scenario description (lead ETH participation FEM).
Data of a three-year survey consist of fungal isolate (no of identification), taxonomic name (as determined by sequences), ability to produce OTA and presence /absence of OT biosynthesis gene. Model as described originally by Batilani and implementation by Storari. OTA biosynthesis related Gene sequences. All Data are available in Storari M. (2012). Characterization and detection of mycotoxins producing black aspergilla from grapes grown in an alpin region Diss. ETH Z. No 20259: Chapter 2 & 3.

T5 D3: A protocol for high-throughput Aspergillus carbonarius contamination of grapes and OTA risk estimation" (ETH).
See protocol in Storari M., Rudolf R., Gessler C., Pertot I., & Broggini G.A.L. (2013) Detection of ochratoxin A-producing *Aspergillus carbonarius* and *A. niger* from grape using the loop-mediated isothermal amplification (LAMP) reaction. Journal of applied microbiology, DOI: 10.1111/jam.12139.

T6 D2-D3: one peer reviewed article on dependency of agro-ecological quality (described as biodiversity and biocontrol ability) on climatic conditions (FEM).
Corneo P.E., Pellegrini A., Cappellin L., Roncador M., Chierici M., Gessler C., Pertot I. 2013. Microbial community structure of vineyard soils across altitudinal gradients and in different seasons. FEMS Microbiology Ecology, DOI: 10.1111/1574-6941.12084.

T6 D2-D3 one peer reviewed article on Biocontrol index for comparing functional activity of phylloplane microbial communities (FEM).
Storari M., Perazzolli M. Puopolo G., Antonielli L. Pertot I. Impact of environmental factors and biocontrol agents on natural microflora in the vineyard. In preparation. To be submitted to BMC genomics.

Activity 3 Assessment of biophysical impacts of climate change at multitrophic level on crops

Task 1. Identification of spatial and temporal dynamics of pest/pathogens of Trentino's major existing crops, their antagonists and their correlation with weather parameters. To obtain a database (DB) of the existing information on pest and pathogens (P/P) of major Trentino's crops (gnoseological starting point of the project) (FEM).
Task 2. Identification of spatial and temporal dynamics of pest/pathogens of selected alternative crops and their antagonists and their correlation with weather parameters (FEM, ARO)
Task 3. Production of EMs from exiting P/P forecast or epidemiological models, the objective is to adjust the existing EMs to be used in the ENVIRO tool (FEM)
Task 4. Retrieval of existing data on area, quality, production and P/P of Trentino's relevant crops. Assembling existing data sets originated from different sources and acquiring missing relevant data on pest and diseases, surface, production and quality of previously mentioned crops, for the validation of the available models with ENVIRO tool (FEM).
Task 5 Implementation of missing models for relevant P/P expected to be relevant in the selected scenarios (FEM).
Task 6. Definition of intra and inter kingdom interactions and food web and their dependency on climate and evaluation of the extent of changes and/or the buffer capacities of the system on the existing relations and interaction under climate changes (FEM, ARO) .
Task 7 Simulation of climate scenarios and their effect on tritrophic interactions among plant, pathogens and biocontrol agents under controlled conditions and comparison of different climates (Mediterranean and alpine) on selected combinations of biocontrol agents, pest/pathogens (artificial inoculation) and crops and on a biocontrol index (FEM, ARO).

The results of this activity are mainly target at increasing the availability of knowledge to be used by extension services and growers in Trentino and will be used in the project to estimate the effect of possible climate changes (scenarios) on current crops and the feasibility of introducing alternative crops.
A DB was obtained including the available models of spatial and temporal dynamics of pest/pathogens of Trentino's major existing crops and their antagonists and their correlation with weather parameters. The DB was used to selected the case studies used in ENVIRO for the simulations. We identified the spatial and temporal dynamics of pest/pathogens of selected alternative crops and their antagonists and their correlation with weather parameters (FEM, ARO).
We produced EMs from exiting P/P forecast or epidemiological models, to be used in the ENVIRO tool ad in particular the model for powdery mildew of grapevine, *Lobesia botrana*, powdery mildew of strawberry and fireblight of apple.
Existing data on area, quality, production and P/P of Trentino's relevant crops were retrieved and used to validate models. Assembling existing data sets originated from different sources and acquiring missing relevant data on pest and diseases, surface, production and quality of previously mentioned crops, for the validation of the available models with ENVIRO tool.
We selected a pest (*Drosophila suzukii*) and two pathogens (*Phomopsis mali* and *Rosellinia necatrix)* which have been expected to be relevant in the selected scenarios and we implemented the missing models. The date were collected based on field observations and experiments under controlled conditions. *D. suzukii* development is positively related to relative humidity and temperature, *P. mali* is strongly related to temperature fluctuation in late winter and early spring and *R. necatrix* development in soil is strongly reduced by high soil water content water and low temperatures, while high temperatures and low water content promote its development.
Since now the complex analysis of definition of intra and inter kingdom interactions and food web and their dependency on climate was extremely difficult. The two plant model systems constituted of an easy to grow annual plant ('alternative crop', tomato), and a 'perennial plant' (existing crop, grapevine) were studied. We studied 2 pathogens, 2 biocontrol agents, and all common leaf saprophytes in a pest/pathogen free greenhouse or growth chambers. Suspensions of sporangia

(*Phytophthora infestans*) and conidia spray (*Oidium neolycopersici*) were applied as inoculum, separately, on tomato leaves. *Erysiphe necator, Plasmopara viticola* were inoculated on grapevine. Lesion development or severity of infection was followed during time. Representatives of bacteria, and yeast (B52, Y13) that are effective in controlling those diseases were used as biocontrol agents. Establishment of the microorganisms on plant leaves was assessed by counting their population density (CFU or RT-PCR) over time. Their antagonist activity was tested as control efficacy against the target diseases. Their side effect on the plant growth was tested. Independent effects of single parameters i.e. temperature, relative humidity, rain, water stress, and combinations of these parameters, on single pest/pathogen, biocontrol agent and plant and their combination: four temperatures (in the range of 15-30°C), four RH levels (70-99%), a set of simulated rain periods, three levels of water stress will be tested on the infection ability of each pathogen, on survival of biocontrol agent populations and on plant growth (composition, photosynthesis, dry weight and leaf surface). We studied the effect of climatic factors on combinations of multiple pest/pathogen, biocontrol agent and plant. Selected pathogens (2) and biocontrol agents (2) were applied at the same time and will be followed for two weeks under conditions that combine general scenarios (previously identified) i.e. low temperature (15°C) combined with simulated rain (10 mm every day) vs. higher temperature (30°C) simulated rain (3 times 50 mm 5 day interval). The two regimes had a strong effect on the pathogens as well as on the two biocontrol agents. The bacterium B52 was strongly affected by high temperatures and low RH and disappears after few days. The yeast Y13 is more resistant to high temperatures and low RH. Powdery mildew increases the survival of the bacterium either by providing a physical shelter or nutritional factors which can sustain the growth of the bacterium. No side effect on the plant have been detected.

In another system evaluated the influence of low/high temperature combined to reduced watering on the interaction between *B. amyloliquefaciens* strain S499, pathogens (*Podosphaera xanthii, Botrytis cinerea and Phytophthora infestans*) and plants (tomato, zucchini, bean) resulting in the induction of systemic resistance (ISR). A reduced level of ISR efficacy was observed when plants were submitted to stress before bacterization, but root treatment with S499 prior to stress exposure attenuated such negative effect. Colonization of S499 during exposure to stress globally allowed the three plants to conserve their ability to mount defense lines to a similar degree at all tested temperatures. Further investigation revealed that production of the ISR elicitor surfactin by S499 is clearly enhanced at low temperature allowing to counter-balance the reduced rhizosphere fitness (colonization, motility, biofilm formation) observed under cold.

A third model system (soil) potted strawberry plants, soil treated with *Trichoderma atroviride* and *Armillaria mellea* was studied. Population dynamic of the pathogen, the biocontrol agent and the natural community were compared in sterilized and non sterilized soils under different soil temperatures (15° and 25°). Disease incidence, biocontrol activity and *T. atroviride* presence was monitored after 6 months. DGGE was used on soil samples collected over time, to test relative changes in natural microbial populations. No significant changes in pathogen populations and Trichoderma have been highlighted between the two temperatures. Therefore we implemented a more sophisticated model system. A synthetic soil was implemented and populated by 12 microorganisms commonly found in soil and whose genome is available. The genome of *T. atroviride* was available. *A. mellea* was sequenced. The pathogen and the biocontrol agent have been introduced in the synthetic soil system. RNA was extracted, cDNA obtained and sequenced. The analysis of the metatranscriptome allows understanding the major changes in the artificial soil populations in presence of the pathogen or the biocontrol agents.

To study the interaction among *A. mellea* and *T. atroviride* we developed a new method. The study of the interactions among microorganisms, especially between pathogens and other microorganisms, is a very useful way to identify possible biocontrol agents (BCAs). In this study we verified the capability of delta C-13 analysis using isotope ratio mass spectrometry (IRMS) to detect active parasitism or metabolic assimilation of C-13-labeled *A. mellea* (plant pathogen) by *Trichoderma atroviride* and *Pseudomonas fluorescens* (two BCAs). The three microorganisms were labeled in pure-culture using a specific medium to which D-glucose C-13 was added. The delta C-13 analysis of mycelia/ cells and DNA was undertaken using IRMS at different times, to study the

uptake kinetics of C-13. The mechanisms of interaction were studied by implementing dual-culture tests and measuring the delta C-13 values of the two BCAs after 29 days of contact with the labeled pathogen. *A. mellea* absorbed C-13 more slowly (plateau at 21 days) than *T. atroviride and P. fluorescens* (3 and 1 day, respectively) in pure-culture. The maximum delta C-13 values were higher in *A. mellea* and *T. atroviride* mycelia (8,019.9 parts per thousand and 10,383.7 parts per thousand, respectively) than in *P. fluorescens* (953.4% in cells). In dual-culture the mycelia of *T. atroviride* which remained in direct contact with labeled *A. mellea* showed an increased delta C-13 value with respect to the unlabeled treatment (66.4% and -26.6 parts per thousand, respectively), due to active interaction. Lower assimilation of C-13 was detected in *P. fluorescens*.
We simulate two climate scenarios under controlled conditions and test them on the interaction of players in the multitrophic system. The multitrophic interactions in the model systems was the previously mentioned. The development of the two pathogens on the plants was modeled.
The potential of biocontrol activity was not evaluated the biocontrol index (already developed for late blight on potato, IASMA unpublished results) because on grapevine it did not gave consisten results.

Deliverables (see table for additional information)
T1 D1: A DB of pest and pathogens reported on grapevine, apple, berries (FEM) and available models for spatial and temporal dynamics of pests/pathogens from literature was created with Microsoft Access.

T2 D2: A list of alternative crops in some selected scenarios taking into account agronomical methods, adaptability to climate change scenarios, potential market was established (ARO-FEM-UNITN).

T2 D3: A list of pest and pathogens reported on the selected alternative crops and available models for spatial and temporal dynamics of pests/pathogens on alternative crops from literature was created (ARO).

T2 D3: A list of effective control measures and known biocontrol agents/hyperparasites of pests/pathogens of grapevine, apples, berries was prepared (FEM-ARO).

T3 D1-D3: Some P/P physiological models to be used in the ENVIRO tool have been adapted and validated; powdery mildew of grape, Lobesia botrana, fireblight of apple, powdery mildew of strawberry (FEM-FBK).

T3 D2 The most economically important P/P present in Trentino or potentially immigrating to Trentino have been identified in *Drosophila suzukii, Phomopsis mali* and *Rosellinia nectrix* (IASMA-ARO).

T4 D1: Historical data pool on P/P and quality to be used for the validation of models in ENVIRO tool have been collected and used for the validation of the models (FEM).

T4 D2: List of existing and available data on pest/diseases, quality and production on grapevine, apple, berries in Trentino have been created and validated in the ENVIRO tool (FEM-ARO-FBK).

T4 D3: Prototype tested and 1 scientific publication together with Activity 1 (ALL).
ENVIRO was validated and a publication was produced:
Caffarra, A., Rinaldi, M., Eccel, E., Rossi, V., Pertot, I. (2012) Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. Agriculture, Ecosystems and Environment, 148: 89–101.

T5 D3: Three models for poorly investigated P/P but potentially becoming epidemic in Trentino have been built (FEM-ARO).

T5 D3: Minimum of one peer reviewed article on biology or epidemiology of P/P (FEM-ARO).
Cini, A., Ioriatti, C., Anfora, G. (2012). A review of the invasion of *Drosophila suzukii* in Europe and a draft research agenda for integrated pest management. Bulletin of insectology, 65: 149–160.

T5 D2: Two peer reviewed articles: Identify the parameters that play a role in the model systems for studying the effect of multitrophic interaction (ARO, FEM).
Pertot I., Agra, O., Rav David, D., Elad Y. Multiple interaction in complex systems: tomato and grapevine. Manuscript in preparation. To be submitted to Phytopathology.
Pertot I. Puopolo G. Hosni T., Pedrotti L., Jourdan E., Ongena M. Modulation of surfactin production explains the success of the interaction between plants and Bacillus amyloliquefaciens S499 at different temperatures. Submitted to ISME Journal on February 27th, 2013.

T6 D2: Two peer reviewed articles on the effect of relevant parameters on the interactions of the multitrophic systems, (ARO, FEM).
Pellegrini, A., Corneo, P.E., Camin, F., Ziller, L., Tosi, S., Pertot, I. (2012). Studying trophic interactions between a plant pathogen and two different antagonistic microorganisms using a C-13-labeled compound and isotope ratio mass spectrometry. Rapid communication in mass spectrometry, 26: 510–516.
Pellegrini, A., Corneo, P., Camin, F., Ziller, L., Tosi, S., & Pertot, I. (2013). Isotope Ratio Mass Spectrometry identifies soil microbial biocontrol agents having trophic relations with the plant pathogen *Armillaria mellea*. Applied soil ecology, 64: 142–151.

T7 D3: One peer reviewed article on comparison of the model systems in two natural environments, how can climate influence tritrophic interactions (current alpine environment, S. Michele, and Mediterranean climate, Tel Aviv) (ARO, FEM).
Pertot I., Elad Y., Dolci C., Merler S. The influence of climate on combines infections of pathogens on grapevine and tomato. Manuscript in preparation. To be submitted to applied environmental microbiology.

Activity 4 Development of highly innovative tools for adaptation in crop management (i.e. expert systems, decision support systems, biocontrol agents, vibration based mating disruption, etc.) to the forecasted/expected changes.

Task 1 Identification of suitable adaptation strategies to be applied in the most likely future scenarios to preserve quality and suppress P/P (ARO, FEM).
Task 2 Scaling-up from prototypes to field applications.
Task 3 To implement a web-based platform to include, manage and optimize the adaptation tools developed in the previous tasks.
Task 4 Identification and analysis of agronomic feasibility of new adaptation tools (as new varieties obtained by marker assisted breeding for traits of interest, trans or cis-genic varieties, new agronomical technologies, new land use, etc.) that may be suggested in a view of climate change in the future (50-100 years).

Induced disease resistance in plants is a physiological state of enhanced defensive capacity elicited by specific stimuli, whereby the plant's innate defenses are potentiated against subsequent challenges. This enhanced state of resistance is effective against a broad range of pathogens and parasites, including fungi, bacteria, viruses, and nematodes. The two most clearly defined forms of induced resistance are Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR). The changing environmental conditions may lead to changes in the activity and survival of organisms. Powdery mildew (*Podosphaera aphanis*) is one of the major fungal diseases of strawberry (*Fragaria* × *ananassa*) world-wide and is expected to increase its distribution under changing climatic conditions. We identified insuced resistance as one of the major mechanisms to be explored to find solutions against pathogens. Induced resistance in strawberry plants under the changing environmental conditions that are expected due to global warming. Inducers that are tested in the present study include *Trichoderma harzianum* T39, acibenzolar-S-methyl (BTH, Bion), a new SCNB2 inducer and isolates of a bacterium B52 and a yeast Y153. These agents not only effectively suppressed powdery mildew on leaves when sprayed on the canopy, but also induced systemic resistance when applied to the root zone while disease was evaluated on the leaves. Similarly lower leaf application resulted in upper leaf disease suppression. Plant growth was enhanced in the presence of the biological inducers in the root zone, especially under limited irrigation conditions. The effect of different temperatures and water stress conditions on induced resistance were studied. The induced resistance agents, that can serve as adaptation agents, had a positive effect on plant growth. However, the plant growth conditions affect the activity of the inducers and ability to induce disease suppression. This is evident with drought and with temperatures. Interestingly, some of the negative effect of a biotic conditions is nullified the inducers.
The mode of resistance that is induced by root zone-applied T39 and BTH towards *P. aphanis* was studied in strawberry plants. The two agents were applied to the soil at two different concentrations 2-3 days before inoculation, with or without an additional application on the day of pathogen inoculation. Both agents induced significant resistance to the diseases on leaves. In this system real-time quantitative PCR was used to examine the effects on expression of defense-related genes in strawberry leaves. One day after the drenching of strawberry roots, T39 and BTH had affected the expression of PR-encoding genes; FaPR1 expression was induced by 2- and 5-fold, Faolp2 expression by 55- and 8-fold and Fra a3 expression by 4- and 22-fold following treatment with BTH or T39, respectively. The level of Falox expression was not affected by BTH treatment, but did increase ~5-fold following treatment with *T. harzianum* T39. Inoculation of foliage with *P. aphanis* increased the expression level of FaPR 1 and Fraa33 (~3-fold increase), as well as Faolp2 (~91-fold) and FaLox (~2-fold) 1 day after inoculation. Drenching with T39 or BTH increased Faolp2 expression one day post infection, but no priming effect could be observed.
Grey mould (caused by *Botrytis cinerea*), is a major fungal disease of the alternative crop-tomato (*Solanum lycopersicum*) world-wide**.** We aimed at shedding light on defense-related gene

expression involved in the induced resistance against *B. cinerea* in tomato plants by the control agents BTH and T39. In whole plants submitted to drenching treatments, transcriptional changes related to the phytohormones salicylic acid and ethylene were induced by benzothiadiazole, while jasmonic acid related changes were induced by T39. On detached leaves treatment by T39 lead to enhanced resistance to *B. cinerea* infection which was proportional to the concentration of the T39 suspension applied. After 5 days of infection, drenching with the 0.04% suspension led to a reduction rate of the disease of 62% compare to the untreated plants, while drenching with 0.4% suspension gave a 84% reduction. Interaction between *B. cinerea* infection and control agents treatment in detached leaves revealed that drenching with T39 suspensions induces systemic resistance against *B. cinerea* and priming of salicylic acid and ethylene-related gene expression proportionally to the fungus concentration. In the same system BTH treatment induced resistance against grey mould independently of salicylic acid and led to strong priming of two genes known for their role in defense against *B. cinerea*, *Pti5* and *PI2*.

SCNB2 is a protein extract which induced resistance on plants. The level of efficacy was tested in different plant/pathogen systems: powdery mildew of strawberry, powdery mildew of cucurbits and powdery mildew of grapevine. SCNB2 was used solo and in combination alternation with *Ampelomyces quisqualis* and low dosages of sulphur.

A. quisqualis ITA3 was selected as potential biocontrol agent against powdery mildews, which are projected to increase in summer with climate change. *Lysobacter capsici* PG4 was selected as biocontrol agents against downy mildew of grape and late blight of potatoes, which are supposed to increase in spring. The biocontrol agents have ben characterized for the level of efficacy, the time of application and the combination with activators (chitinases) or low dosages of copper.

Biochar is the solid co-product of biomass pyrolysis, a technique used for carbon-negative production of second generation biofuels. The biochar can be applied as a soil amendment, where it permanently sequesters carbon from the atmosphere, as well as improves soil tilth, nutrient retention, and crop productivity. In addition to its other benefits in soil, we found that soil-applied biochar induces systemic resistance to the foliar fungal pathogens *B. cinerea* and *Leveillula taurica* (powdery mildew) on pepper and tomato and to the broad mite pest (*Polyphagotarsonemus latus* Banks) on pepper. Levels of 1-5% biochar in a soil and a coconut fiber:tuff potting medium were found to be significantly effective at suppressing both diseases in leaves of different ages. In long term tests (105 days), pepper powdery mildew was significantly less severe in the biochar treated plants than in the plants from the unamended controls, although during the final 25 days, the rate of disease development in the treatments and controls was similar. Possible biochar-related elicitors of systemic induced resistance are discussed.

Various biochars added to soil have been shown to improve plant performance. We explored the ability of wood biochar and greenhouse waste biochar to induce systemic resistance in strawberry plants against *B. cinerea*, *Colletotrichum acutatum* and *P. apahanis*, and to examine at the molecular level some of their impacts on plant defense mechanisms. Disease development tests on plants grown on 1 or 3% biochar-amended potting mixture, and quantification of relative expression of 5 plant defense-related genes (*FaPR1*, *Faolp2*, *Fra a3*, *Falox*, and *FaWRKY1*) by real-time PCR were carried out. Biochar addition to the potting medium of strawberry plants suppressed diseases caused by the three fungi, which have very different infection strategies. This suggests that biochar stimulated a range of general defense pathways, as confirmed by results of qPCR study of defense-related gene expression. Furthermore, primed-state of defense-related gene expression was observed upon infection by *B. cinerea* and *P. aphanis*. The ability of biochar amendment to promote transcriptional changes along different plant defense pathways probably contributes to its broad spectrum capacity for disease suppression.

To investigate the induced resistance pathway mediated by biochar in tomato – *B. cinerea* interaction, the following activities were carried out: (a) quantitative disease assay on two commercial tomato cultivars and three wild types with their mutant or transformant for ethylene, jasmonic acid and salicylic acid; (b) detection of early H_2O_2 accumulation associated with biochar-mediated resistance as a response to *B. cinerea* inoculation; and (c) expression analysis of the effect of biochar amendment on defense-related genes on the whole plant, and on detached leaflets

inoculated with *B. cinerea* or mock. Greenhouse waste biochar produced at 350 and 450ºC (GHW-350, GHW-450), wood biochar, and powdered activated carbon amendments at 1 or 3% w/w induced resistance to *B. cinerea* in tomato. Despite the fact that different biochars were used and the effect of a given biochar somehow varied in a cultivar-dependent manner, the disease severity was significantly reduced in all tested tomato cultivars. On top of this, the amendment of potting mix with GHW-450 induced resistance to *B. cinerea* in an ethylene insensitive mutant, *Never ripe*, and in a transgene that cannot accumulate salicylic acid, NahG, but not in a jasmonic acid deficient mutant, *def1*. Besides, stronger and earlier H_2O_2 accumulation observed as a result of the biochar amendment subsequent to *B. cinerea* inoculation across the wild types and their mutant/transgene except for *def1*. Biochar amendment induced the expression of *PI2*, *TomLoxA*, *TomLoxC*, *TomLoxD*, *Pti4*, *Pti5*, *GluB*, *CHI9*, *SAMT*, *ACO1*, and *PR1a* at least in one of the genotypes; and similarly following *B. cinerea* infection, except *TomLoxA* and *TomLoxC* the transcription level of the rest the genes mentioned were induced. In the case of *def1*, however, biochar amendment hardly affected the expression of these genes. In conclusion, the results from the quantitative disease assay and induction of genes expression strongly suggest that jasmonic acid signaling pathway is important for biochar-mediated resistance to *B. cinerea* in tomato.

In conclusion, It was predicted that diseases of the crops in question will become more severe within time and measures to combat these problems will need to be powerful and intensive. Treatments that were tested in the different plant-pathogen systems included BCAs from our collection or commercially available, friendly control agents (both resistance inducers or biocides. We focused on P/P, which indicate a potential high impact in the selected scenarios of Activity 1, and we developed new environmentally sound control measures and adjusted agronomic practices for the optimization of plant protection and agronomic management. A climate change reflection on the biotic and abiotic stress as well as on the control agents was described. Moreover, we studied the mode of action of the inducers and we could show an adaptation as well as mitigation role in the researched systems.

The selected products have been scaled up for field application. *T. harziamum* T39, *A. quisqualis* ITA3, *L. capsici* PG4, bacterium B52 and yeast Y13 production have been implemented for medium volumes. Condition of fermentation, prototype formulation have been implemented. Products have been tested under field or greenhouse conditions under randomize block design.

Different source of proteins for SCNB2 have been tested under field and greenhouse conditions especially focusing on the reduction of content of NaCl. Different activators of germination of *A. quisqualis* ITA3 were compared in term of increased germination and biocontrol efficacy.

We identified new product technologies to be used in the adaptation to climate change.

Inducers tested that generated positive results:

- *Trichoderma harzianum* T39- a biocontrol agent,
- acibenzolar-S-methyl (BTH, Bion),
- The new SCNB2 inducer,
- a bacterium B52
- a yeast Y13.

They gave:

- Effective suppression of PM when sprayed on the canopy.
- Systemic resistance when applied to the root zone while disease was on the leaves.
- Lower leaf application resulted in upper leaf disease suppression.
- Plant growth was enhanced in the presence of the biological inducers in the root zone, especially under limited irrigation conditions (abiotic future stress).
- The induced resistance agents, that can serve as adaptation agents, had a positive effect on plant growth at different temperatures and water stress conditions. However, the plant growth conditions affect the activity of the inducers and ability to suppress disease under drought and temp. conditions.
- Some of the negative effect of a biotic stress conditions is nullified by the inducers.

Biochar is a carbon-negative product that was applied as a soil amendment, where it permanently sequesters carbon from the atmosphere which:.

- Soil-applied biochar induces systemic resistance to the foliar fungal pathogens of tomato and sweet pepper.
- In long term tests, pepper powdery mildew was significantly less severe in the biochar treated plants than in the plants from the unamended controls.
- Induce systemic resistance was found in strawberry plants against *B. cinerea*, *Colletotrichum acutatum* and *P. apahanis*.
- Greenhouse waste and wood biochars produced at 350 and 450ºC amendments induced resistance to *B. cinerea* in tomato. Effect of a given biochar somehow varied in a cultivar-dependent manner,
- The results from the quantitative disease assay and induction of genes expression strongly suggest that jasmonic acid signaling pathway is important for biochar-mediated resistance to *B. cinerea* in tomato.

In addition we scaled up the following agents:

- New strain of *Ampelomyces quisqualis* ITA3 characterized and scale up production and formulation to medium volumes.
- An activator of ITA3 based on chitin characterized and scale up production.
- New strain of *Lysobacter capsici* PG4 to be used in combination with low dosages of copper and scale up of production to medium volumes.
- SCNB2 conditions of application and scale up production, in collaboration with Manica spa, a company in Trentino.

In conclusion, treatments that were tested in the different plant-pathogen systems included BCAs from our collection or commercially available, friendly control agents (both resistance inducers or biocides.

- We focused on P/P, which indicate a potential high impact in the selected scenarios of Activity 1, and we developed new environmentally sound control measures and adjusted agronomic practices for the optimization of plant protection and agronomic management.
- A climate change reflection on the biotic and abiotic stress as well as on the control agents was described.
- We studied the mode of action of the inducers and we could show an adaptation as well as mitigation role in the researched systems.

A prototype web tool was developed for further development (possibly through a dedicated spin-off activity). The tool was developed for use by growers to identify diseases and for taking crop management decisions to manage disease under climate climate change. The specification supports the customization with the specific needs of a farm. The first system, called identificator, allow the identification of pest and disease based on visual recognition of symptoms. The second system called Monberry is developed to manage the treatments in a crop. In both cases strawberry was use as case study, however both systems are design to be adapted to any crop.

A second web-based DSS was further developed on grapevine. The DSS included the customization for the single grower, the management of powdery and downy mildew and grey mould and indicates the time for other actions (as placing the dispensers for mating disruption). The system was tested under field conditions and developed in collaboration with R&D systems a company in Trentino.

A study was conducted based on some present selected scenarios, to identify the possible tools to be explored, their feasibility, and the ratio cost. The results of the study indicate that the optimal tool is a cis-genic plant with resistance against the key pest/pathogen that will be relevant in the future. However this tool will require his costs and long term development, therefore biopesticides combined with DSS are at the moment in term of cost/benefit the recommended tools to cope with climate change.

Deliverables (see table for additional information)

T1 D3 Means to suppress P/P that are intensified with climate change (FEM-ARO).

T. harzianum T39- a fungal biocontrol agent from ARO,
acibenzolar-S-methyl (BTH, Bion),
SCNB2, originally developed in collaboration between FEM and ARO
a bacterium B52, a FEM isolate
a yeast Y13, an ARO isolate
Various biochars
A. quisqualis ITA3
L. capsici PG4
An activator of ITA3

T1 D3 Alternative agricultural systems (FEM-ARO).
As climate is warming up, it is expected that larger areas in Trentino will be exposed to higher temperatures, more sunny days, shorter winter and longer summer. Conditions in the fall and spring will be milder. In some areas it will be possible to grow in the open some field crops or fruit trees that originate from warmer regions and greenhouse crops. A list of suggested crops and current varieties that fit the new climatic scenario was formed, yet with potential pests and diseases. Among the alternative crops are tomato, cucumber, potato, and other highly valuable agricultural plants.

T1 D3 At least two peer reviewed articles on environmentally sound means to suppress P/P (FEM-ARO).
Elad Y., Rav David D., Meller Harel Y., Borenshtein M., Ben Kalifa H., Silber A. and Graber E.R. (2010) Induction of systemic resistance in plants by biochar, a soil-applied carbon sequestering agent. Phytopathology 100, 913–921.
Graber E.R., Meller Harel Y., Kolton M., Cytryn E., Silber A., Rav David D., Tsechansky L., Borenshtein M. and Elad Y. (2010) Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. Plant and Soil 337, 481–496.
Kolton M., Meller Harel Y., Pasternak Z., Graber E.R., Elad Y. and Cytryn E. (2011) Impact of biochar application to soil on the root-associated bacterial community structure of fully developed greenhouse pepper plants. Applied and Environmental Microbiology 77, 4924–4930.
Graber E., Silber A., Elad Y., Meller Harel Y., Rav David D., Borenshtein M., Shulhani R., Ben Kalifa H. (2011) Induced systemic resistance in plants by soil applied biochar. Shadeh Vayerek 228: 26–32. In Hebrew
Elad Y., Cytryn E., Meller Harel Y., Lew B. and Graber E.R. (2011) The Biochar Effect: plant resistance to biotic stresses. Phytopathologia Mediterranea 50, 335−349. *Review publication*
Meller Harel Y., Elad Y., Rav-David D., Borenstein M., Shulchani R., Lew B. and Graber E. R. (2012) Biochar-induced systemic response of strawberry to foliar fungal pathogens. Plant and Soil 357, 245–257.

T2 D3 Scale up of prototypes, products (FEM).
SCNB2 was scaled up in collaboration with the company Manica.

T3 D3 Prototype of a web-based platform for managing P/P control and quality under climate change; user evaluation (FEM).
Indentificator was developed to help growers to visually identify new pest and pathogens
Sentinella was developed in collaboration with the company R&D systems to manage crop protection on grapevine
Monberry was developed as a platform to manage pest and pathogens on several crops, it was studied on the case study of strawberry

T4 D3 Technologies that could be implemented as adaptation tools in the long term scenario, with cost/benefit and acceptance analysis (FEM-ARO-UNITN).

A list of possible strategies and technologies was prepared: cis-genic resistan plants, biopesticides and DSS are the recommended tools to counteract the effect of climate change on pest and pathogens.

Activity 5 Assessment socio-economic impacts of the most probable scenarios and evaluation of adaptation strategies that can be taken

Task 1 Assembling existing dataset originated from different sources (Farm Accountancy Data Network (FADN-RICA), research centres, cooperatives, extension service, etc.) and acquiring data on spatial coordinates of the farms producing grape and apples in order to construct a fully georeferentiated dataset.
Task 2 Evaluation of the spatial and temporal variability in crop yield and farm income (both calculated from farm accountancy) with respect to climate related variables during the reference period (2003-2007).
Task 3 Understanding the farmer's perception of climate change, how they are affected by climatic conditions, their acceptance of the adaptive strategies that are available to them, and the constraints and opportunities for enhancing their adaptive capacity.
Task 4 Modelling the farmers behaviour in response to climate variation and to the consequent change in pest ecology (type and density)
Task 5 Evaluation of the overall sustainability of the proposed adaptation strategies at the farm and at provincial level.
Task 6 Evaluation at the provincial level of the social acceptability of the proposed adaptation strategies
Task 7 Evaluation of potential alternative crops in case of extreme events in Trentino (This task was eliminated since the very beginning of the project due to the reduction of project budget)

UNITN asked INEA in Padova to extract Farm accountancy data for grape and apple farms in Trentino Alto-Adige region for the 5 years period 2003-2007. The rotating nature of the FADN panel creates an unbalanced panel dataset. Latitude, longitude and altitude have been associated to each farm address of Trentino farms (FADN data) using "*Google earth*" according to both the WGS84 GD and UTM ED50 international system. Given the necessity to associate each farm to spatialised climate variables, we restrict our sample to Trentino province. FBK interpolated average temperature and monthly precipitation for 1961-1990 and 2003-2007 on the entire surface of Trentino according to the methodology provided by Uboldi et al. (2008). We add interpolated climate variables (both climate normals 1961-1990 and annual temperature and precipitation) to each farm. In order to add information on soil characteristics, we extract maps from the European Soil Database (ESDB) maintained by the European Soil Data Centre () and the Italian dataset maintained by the Centro Nazionale di Cartografica Pedologica Firenze (http://www.soilmaps.it/ita/downloads.html). We associated each geo-referenced farm to both the soil maps. For each of the 312 farms soil characteristics corresponding to farm location were manually reported in the dataset. The final dataset contains 886 observation referring to 291 farms producing apple and/or grapes in 2003-2007. A newly created data base will be very useful to develop economic models considering spatial heterogeneity. The final dataset contains information about the 312 farms growing apple and grapes which are included in the Farm Accountancy Data Network in period 2003-2007. It is an unbalanced panel containing 886 observations and 314 variables concerning structural and economic data of farms, soil characteristics and interpolated climate normals (average temperature and precipitation in 1961-1990) and climatic variables referring to the period 2003-2007.
The dataset assembled in T1 has been used to investigate the variability in farm income with respect to climate related variables. The long run effect of climate change have been investigated trough an application of the Ricardian approach. We focused on 140 individual farms growing apple and grape in Trentino both in year 2003 and 2006. Average values of 2003 and 2006 are used in the estimation so that results reflect more than a single year effect. Several models have been estimated to test the use of different climate related variables, the use of different control variables and different functional specifications (linear, log-linear and Box-Cox). The presence of seasonal and interaction effects between averages temperature and precipitation and the presence of spatial

correlation were tested. According to the best model estimates, projections of the effect of climate change have been calculated for each farm and then aggregated for the sample. Estimation results have been presented in international conferences receiving feedbacks on how to improve the models. The panel nature of the sample has not been exploited in the Ricardian analysis but in the analysis of the short run effects of weather. Many problems have to be solved to carry out this analysis. We specify a fixed effect panel data model using an estimator robust respect to heteroskedasticity and correlation, and apply a variables' specification that give us the possibility to consider important time-invariant farm's aspects (i.e. soil typology and slope) among regressors. The results of the explorative analysis of farm performance under different climatic and management conditions can provide a lot of information in order to improve the modelling of agricultural adaptation to climate change (Reidsma et al., 2007, Clim. Change 84:403–422. Structural and technical parameters will be used in the implementation of the bio-economic farm model (task 3). Both the Ricardian model and fixed effect panel model estimated on irrigated farms highlight a hill-shape relationship between farm profitability and climate variables (temperature and precipitation). According to the Ricardian model we can expect a negative impact of climate change on Trentino farms. In the period 2003-2007 net revenues per hectare depend heavily on the values of annual climate variables, on farmer's age and on the values of variables connected with farmer's strategies such as specialization and quality certification and signing an insurance contract.

Data necessary to investigate apple and wine growers' risk perception of climate change, pest and hail risk and risk attitude have been collected through a computer assisted face-to- face survey to 196 farmers (75 winegrowers and 121 apple farmers). The survey was design and carried out to elicit farmers' risk perceptions and risk preferences. We applied the exchangeability method (EM) to elicit risk perception and three different approaches were used to elicit farmers' risk attitude (self-assessment, few euro gamble task and farm income gamble task). To capture the change in perceived risk due to climate change, we elicit risks at two points in time: (i) the risk in the next growing season (short-run risk; unaffected or less affected by climate change) and (ii) the risk 30 years from now (long-run risk; affected by climate change). We elicited risk perceptions of damage by pests and hail. Information about a lot of variables which might influence perception and how these perceptions were built (heuristics) were collected and organized in spreadsheet with 196 complete and usable observations. The relationship between there variables have been investigated through several econometric analyses. Hail risk and crop disease risk perception in the short-run (the then upcoming growing season, 2011) and in the long-run (a more remote future growing season, 2031) are analyzed. Regression analysis is used to test if farmers who believe in climate change show quantitatively higher perceptions of related hazards than farmers who do not believe in climate change. Further analysis of the experimental data on farmers' perceptions of long-run hail risk allowed us to investigate whether farmers use heuristics to form quantitative assessments of climate change related risks. In order to investigate the expert perception of climate change we adapted to the Trentino context the questionnaire kindly provided by some Danish researchers (Olesen et al. 2010). The questionnaire had to be tailored to the Trentino viticulture by adding new limiting factors and new adaptation strategies. The respondents had to evaluate the different items using a Likert scales combining the degree of severity and the direction of effects (increase/decrease). The questionnaire was administered to 14 experts belonging to the viticulture advisory service of FEM. Data were collected between August and September 2011. These qualitative data are organized in tables and graphs. Statistical analysis was impossible because the small number of observations. A survey on farmers' perception of climate change and acceptability of adapting strategies will be of fundamental importance at least for two reasons: 1) to estimate the specific risk aversion against climate change; 2) to improve the communication strategy to be followed by policy makers and experts. From the surveys with farmers, evidence emerged that the majority of interviewed farmers not only are familiar with the perils due to climate change in general but also display quantitatively detectable perceptions of future hazard to their farming operation that are directly or indirectly related to climate change. Another important result that emerged from the work we conducted with farmers is the statistical significant relationship between risk perceptions and risk attitudes. Specifically, we find that farmers who are more (less) risk averse

tend to perceive greater (smaller) probabilities of farm losses occurring. This result has important implications also for future theoretical studies.

Data necessary to model farmers decision of buying insurance have been collected through a two round face to face survey. Apple farmers (317 subjects) completed two stated preference experiments, provided information regarding their actual insurance decisions and many other information on farm's and farmer's characteristics. A new dataset containing 317 complete and usable observations concerning about 100 variables is arranged in an Excel spreadsheet.These data are used for estimating several econometric models to assess whether there is a relationship between risk aversion and subjective probabilities belief of the probability of crop losses due to weather events. Regression analysis is used to investigate the relationship between a farmer's level of risk aversion and his subjective belief of the probability of crop losses. A Probit model estimation is used to test the predictive power of different format of risk attitude elicitation. Actual insurance purchase decision is the dependent variable to explain and risk attitude measures elicited with three different formats are used as explaining variables. Part of the data collected in the context of task 3 (subjective beliefs and perceptions) could be used to complement data collected in the context of task 4 (weather insurance decisions) to achieve the objectives of task 4. To this end, we used econometric analysis in a discrete choice experiment framework to assess farmers risk aversion using data on insurance actual decisions and farmers' subjective beliefs. The analysis also assesses which farmer and farm characteristics are relevant to predict risk attitudes. In addition this analysis shed light on the ability of subjective believes to play a role in improving empirical estimates of risk aversion. Therefore this study represents a methodological contribution to the empirical literature on the measurement of individual risk attitudes. The different bio-economic models will allow us to highlight different optimization strategies according to differences in structural and technical parameters and personal risk preferences. The experimental component of our study has revealed the importance of a realistic framework to be applied in gamble task experiments used to elicit. Specifically, from a methodological point of view we find that only a gamble task defined in terms of farm income is good in predicting farmers insurance purchase decisions.

Given the impossibility to collect data on adaptation strategies, we evaluated the sustainability at a farm level and for a case study (IASMA farm). The application of Dexipm tool for sustainability assessment of adaptation strategies, required a tailoring of the tool. Research desk and brainstorming sessions lead to the identification of 3 new indicators to be added to the Dexi tool for better cover the social dimension of sustainability. The indicators added to the attribute "farmer and employees knowledge and skills" are Awareness of ecological relationship, Representativeness in social institutions e Additional training. Meeting with experts FEM provided economic and environmental data associated to the four strategies to be evaluated (variety switch from Mueller Thurgau to Chardonnay, crop switch from viticulture to cherry orchards, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones). For collecting information about social sustainability indicators a questionnaire has been designed and administered to some experts. Quantitative data provided by FEM and qualitative indicators on social sustainability collected through the survey questionnaire were inputted by FEM into the Dexipm software tool. An overall sustainability evaluation of the different alternatives will be increase the information available to support policy decision making. The analysis of sustainability of four adaptation strategies (variety switch, crop switch, adoption of anti-hail nets, change of the irrigation system from sprinkler to drip ones) highlights only small difference in terms of sustainability among the selected adaptation strategies in the specific case study. More interestingly the Dexipm tool emerges as a flexible and suitable tool for assessing sustainability of adaptation strategies at the farm level.

In order to gain insights into consumers' preferences for apples produced with low environmental impact techniques, we carried out a Choice Experiment (CE) in the field on apples' consumers. We investigated consumers' preferences and willingness to pay for 4 different attributes of apples; 1) production's method (organic, integrated pest management, IPM with extensive use of biocontrol agents, conventional) 2) visual aspect 3) origin 4) produced with low greenhouse gas emissions practices. A special section of the CE was designed as to elicit the use of threshold values (cut-offs) as heuristic in buying behavior. Three treatments were included in the CE: a pure hypothetical, a

hypothetical with cheap talk and a real payment treatment. Data were collected through intercept face-to-face survey in 4 supermarkets in Trentino. Data collected with the 288 questionnaires were analyzed with the different econometric approaches available for discrete choice data (multinomial logit, random parameter logit, latent class). For the analysis of the use of thresholds we apply the Swait' s model (2001).
To investigate people preference for adaptation strategies to adopt in the future (2030) we had to move from actual consumers to taxpayers. A CE was designed by UNITN to investigate the population perception of having apples containing pesticide residues in 2030 as a consequence of different crop protection strategies (chemical, biological control, pest resistant varieties). First, two focus-group interviews with 10 participants each were carried out to identify alternatives, attribute, and levels to be used in the ultimate CE field survey. After a pre-test CE field survey on 80 subjects, the ultimate CE field survey was designed and the survey software was prepared. The survey contained a section for the elicitation, trough the EM method, of risk perception about the number of apples containing pesticide residues in 2030.
The experimental design is a D-efficient homogeneous pivot design which allows us to introduce subjective risk estimate into the CE. Among the 797 taxpayers interviewed, 487 respondents were assigned to the treatment group in which each subject is presented with a SQ alternative which incorporates her/his subjective risk estimate. Other 310 respondents were presented with a SQ's risk level which differ from her/his subjective risk estimate. Data were collected by trained interviewers from a survey company (OGP) using the computer-assisted personal interviewed (CAPI) system which consists in face-to-face interviews usually conducted at respondents' home or business via laptop. Data obtained from each subject were automatically stored in a central computer. Data were analyzed with the different econometric approaches available for discrete choice data. The acceptability by the local population is of fundamental importance for the success of any policy or adaptation strategy. The CE on 288 apple consumers has revealed that consumers are currently willing to pay only for organic production method but dislike IPM or IPM using biological control agents extensively. Consumers are willing to pay for mitigation practices that reduce the greenhouse gas emissions. From the CE on 797 taxpayers it emerges that Trentino dwellers expect an increase in the number of apples containing pesticide residues in 2030 (75 out of 100 with a 50% change). The average marginal WTP for supporting R&D aiming at a reduction from 75 to 15 apples containing pesticides is small (around 1,2 euro per taxpayer per year).

Deliverables (see table for additional information)

T1 D1: list of existing and available data on temperature, rainfall quantity and distribution and on farm accountancy was created.
The observation network of Autonomous Province of Trento (PAT) provides data registered in Trentino in the last fifty years on the air temperature and daily precipitation. The Farm Accountancy Data Network (FADN) provides extensive information about farm structure and assets, production costs and revenues, and some strategic choices (for instance quality certification, insurance purchase) for the period 2003-2007. Soil characteristics are not available for Trentino province but can be downloaded from the Italian database of soil maps (http://www.soilmaps.it/ita/downloads.html) and the European Soil Database (ESDB) maintained by the European soil data centre (http://eusoils.jrc.ec.europa.eu/).

T1 D2: list of meteorological variables that most influence yield and quality of the reference crops was created. According to the results of our models, average temperature and average precipitation both influence the economic farm profitability of irrigated farms in the long and short run.

T1 D3: new Data Base which integrates all the interesting data (spatial coordinates, meteorological variables, structural and economic data). The dataset containing information about the 312 farms growing apple and grapes which are included in the Farm Accountancy Data Network in period

2003-2007 is completed and verified. It contains farms, soil an farmers characteristics, farm spatial coordinates and interpolated climate variables.

T2 D2: one peer reviewed article on the effect of climate on economic performance of homogeneous groups of farms.
De Salvo M., Raffaelli R., Moser R. The impact of climate change on permanent crops in an Alpine region: A Ricardian analysis, accepted with minor revision to Agricultural System.
De Salvo M., Raffaelli R. The effect of annual weather on permanent crops in Trentino, paper under preparation.

T2 D2: the list on the most important variables influencing the economic performance of Trentino' farms.
The estimated fixed effect model suggests that farms' profitability depend heavily on the values of annual climate variables, farm's physical dimension and input indicators related to mechanization, capitals and employment levels, on farmer's age and on the values of variables connected with farmer's strategies such as specialization and quality certification and insurance purchase.

T3 D3: one peer reviewed article on Analysis of farmers' perception of climate change and one peer reviewed article on willingness to adopt different mitigating/adapting strategies
Menapace L., Colson G. Raffaelli R. (2013) Risk Aversion, Subjective Beliefs, and Farmer Risk Management Strategies, American Journal of Agricultural Economics 95(2): 384–389. DOI: 10.1093/ajae/aas10.
Menapace L., Colson G. Raffaelli R. "Cognitive heuristics and farmers' perceptions of risk related to climate change" paper presented at the AAEA annual meeting Seattle 2012.

T3 D3: several bio-economic farm models for different groups of farms
As described above, the development of a bio-economic simulation farm model, as planned in the original version of the project, resulted to be unfeasible.

T4 D3: one peer reviewed article on Modelling farmers' behaviour in response to risk and uncertainty associated to climate change.
Menapace L., Colson G., Raffaelli R. Do individual risk attitude measures predict insurance decisions? Submitted to Journal of economic behavior & organization.
Menapace L., Fezzi C. Estimating risk preference from insurance choices using subjective beliefs, paper under preparation

T5 D3: one peer reviewed article on the sustainability of different strategies.
Rizio D., Raffaelli R., Colombini A., Pertot I. Evaluation of overall sustainability of selected adaptation strategies in viticulture with Dexipm, paper under preparation.

T6 D3: two peer reviewed articles, one on the results in terms of the willingness to accept or to support the different adaptation strategies, the other on the methodological issues related with the design of the choice experiment.
Moser R., Raffaelli R. (2012) Consumer preferences for sustainable production methods in apple purchasing behaviour: a non-hypothetical choice experiment. International Journal of Consumer Studies, 36 (2): 141–148. DOI: 10.1111/j.1470-6431.2011.01083.
Cerroni, W.D. Shaw, (2012). Does climate change information affect stated risks of pine beetle impacts on forests? An application of the exchangeability method. Journal of Forest Policy and Economics. DOI: http://dx.doi.org/10.1016/j.forpol.2012.04.001
S. Cerroni; S. Notaro; W.D. Shaw**,** (2012) Eliciting and estimating valid subjective probabilities: An experimental investigation of the exchangeability method in: Journal of economic behavior & organization 84: 201–215 . DOI: 10.1016/j.jebo.2012.08.001.

Cerroni S., Notaro S., Shaw W.D. “How many bad apples are in a bunch? An Experimental Investigation of Perceived Pesticide Residue Risks”, submitted to Food Policy.

Moser R., Raffaelli R. Notaro S. Testing the hypothetical bias in Choice Experiments: a Real CE using respondent’s own money, under review of European review of Agricultural economics.
Cerroni S., Notaro S., Raffaelli R. Introducing subjective probabilities into choice experiments to test scenario adjustment, paper under preparation.
Moser R., Raffaelli R., Pertot I. Are consumers adopting the same decision making pattern in fruit purchasing? An exploratory analysis on apples and small fruits**,** paper under preparation.

T7 D3: a peer reviewed article on the study of the potential crops that could substitute existing crop in case of extreme event and peer reviewed article on the analysis of the future impact of these new alternatives.
Deleted since the beginning of the project

Final GANTT diagram

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
A1		**Activity 1 Assessing the effects of climate change Trentino agro-ecosystems: the ENVIRO tool**																																																
A1	T1	Development of an integrated EM/GIS analysis tool for Trentino's major agricultural pests (ENVIRO)																																															
A1	T2	Construction of weather scenarios																																														
A1	T3	Integration of GIS, meteorological and field data and remote sensing data																																														
A1	T4	Prediction under climate change scenarios																																														
A2		**Activity 2 Assessment of biophysical impacts of climate change on quality and production of crops of Trentino**																																														
A2	T1	Direct effect of climate change on quality and production indices																																														
A2	T2	Genomic to phenology: effect of climate change (ontogenic resistance)																																														
A2	T3	Genomic to plant health: effect of climate change on plant self-protection (induced resistance)																																														
A2	T4	Indirect effect of climate change on fruit quality																																														
A2	T5	Indirect effect of climate change on food quality (mycotoxins contamination of fruits)																																														
A2	T6	Evaluation of agro-ecological quality: biodiversity and biocontrol under climate change																																														
A3		**Activity 3 Assessment of biophysical impacts of climate change at bi and tritrophic level on crops**																																														
A3	T1	Identification of spatial and temporal dynamics of pest/pathogens of Trentino's major existing crops and their antagonists and their correlation with weather parameters																																														
A3	T2	Identification of spatial and temporal dynamics of pest/pathogens of selected alternative crops and their antagonists and their correlation with weather parameters (dynamics)																																														
A3	T3	Production of EMs from exiting P/P forecast or epidemiological models, the objective is to adjust the existing EMs to be used in the ENVIRO tool (modeling).																																														
A3	T4	Retrieval of existing data on area, quality, production and P/P of Trentino's relevant crops (model validation)																																														
A3	T5	Implementation of missing models for relevant P/P expected to be relevant in the selected scenarios																																														
A3	T6	Definition of intra and inter kingdom interactions and food web and their dependency on climate and evaluation of the extent of changes																																														
A3	T7	Simulation of climate scenarios and their effect on tritrophic interactions and comparison of different climates (Mediterranean and alpine)																																														
A3	T8	Interaction between insects and their pathogens.																																														
A4		**Development of highly innovative tools for adaptation (i.e. expert systems, decision support systems, biocontrol agents, vibration based mating disruption, etc) to forecasted changes**																																														
A4	T1	Identification of suitable adaptation strategies to be applied in the most likely future scenarios to preserve quality and suppress pest/diseases.																																														
A4	T2	Scaling-up from prototypes to field applications.																																														
A4	T3	A web-based platform to be implemented to include the adaptation tools developed in the previous tasks																																														
A4	T4	Identification and analysis of feasibility of new adaptation tool																																														
A5		**Assessment socio-economic impacts of the most probable scenarios and evaluation of adaptation strategies that can be taken**																																														
A5	T1	Assembling existing socio-economic dataset originated from different sources (Farm Accountancy Data Network, meteorological stations, research centers)																																														
A5	T2	Evaluation of the variability in crop yield and farm income (both calculated from farm accountancy) with respect to climate related variables during the reference period (2003-																																														
A5	T3	Understanding the farmer's perception of climate change, how they are affected by climatic conditions, their acceptance to the adaptive strategies that are available to them, and the constraints and opportunities for enhancing their adaptive capacity.																																														
A5	T4	Modeling the farmers behavior in response to climate variation and to the consequent change in pest ecology (type and density) and agronomical aspects																																														
A5	T5	Evaluation of the overall sustainability of the proposed adaptation strategies at the farm and at provincial level																																														
A5	T6	Evaluation at the provincial level of the social sustainability of the proposed adaptation strategies																																														
A5	T7	Evaluation of potential alternative crops in case of extreme events in Trentino																																														
A6	T1	**Project management**																																														

in yellow the original timetible
in orange part of timetable which was not modified
in green the delays in the timetable
in blue the final GANNT

Deliverables

WP	task	year	deliverable	Description of the status/additional information	partner	%
1	T3	D2	ENVIRO tool: integration of weather driven physiologically based ecological models with geographical information system and remote sensing.	Achieved	FBK FEM	100
1	T4	D1	ENVIRO tool: Historical and global warming, temperature and precipitation scenarios included.	Achieved	FBK FEM	100
1	T5	D3	Visualization of vulnerable host areas, ranges of expansion and climatic limits of P/P, under current and global warming scenarios.	Achieved	FBK FEM	100
1	T1-	D3	peer reviewed articles on ENVIRO and its applications.	Caffara et al., 2012	FBK FEM	100
1	T3	D3	peer reviewed articles on ENVIRO and its applications.	In preparation, Rinaldi et al., fire blight to be submitted to …	FBK FEM	100
2	T1	D1	Database of suitable existing quality and production indices for grapevine, apples, strawberries and algorithms to forecast quality and production based on climate	Achieved	FEM	100
2	T1	D2	Identification for each crop of the quality parameters most likely influenced by climate change	Achieved	FEM	100
2	T1	D3	Effect of temperature gradient on fruit quality under climate change scenarios (grape, sugars)	Achieved	FEM	100
2	T2	D3	A peer reviewed article describing the phenology and genomics of ontogenic resistance in relation to temperature	Achieved	ETH	100
2	T2	D3	Linear model describing the development of the ontogenic resistance of leaves in relation to temperature	Achieved	ETH	100
2	T3	D3	A peer reviewed article describing the dynamics of the induced resistance mechanism and its genomics in relation to temperature and drought stress	Roatti et al., stress on ISR	FEM	100
2	T4	D2	A peer reviewed article on genotype-temperature interaction in the progamic phase in apples and strawberries	Paper on preparation only on apple pollen	FEM	80
2	T5	D3	One peer reviewed and one technical article describing the effect of temperature on presence and expression of OTA biosynthesis genes and OTA production by local strains under different temperature and duration of incubation	Achieved as scientific paper	ETH FEM	100
2	T5	D3	One peer reviewed and one technical article describing the automated system of Ochratoxin risk identification through the RT-PCR and its validation	Achived, Storari et al.	ETH FEM	100

2	T5	D3	A complete data set for OTA and grape, with appropriate mathematical models describing the temperature/duration relation to toxin quantity, gene transcription and fungal developments (measured as genome equivalents) to be used for risk scenario description.	Achived	FEM	100
2	T5	D3	A protocol for high-throughput Aspergillus carbonarius contamination of grapes and OTA risk estimation"	Achieved. Lamp-based method for screening	ETH	100
2	T6	D2-D3	One peer reviewed article on dependency of agro-ecological quality (described as biodiversity and biocontrol ability) on climatic conditions	Achieved,	FEM	100
2	T6	D2-D3	one peer reviewed article on Biocontrol index for comparing functional activity of phylloplane microbial communities	Storari phyllosphere paper under preparation	FEM	90
3	T1	D1	List (DB) of pest and pathogens reported on grapevine, apple, berries and available models for spatial and temporal dynamics of pests/pathogens from literature.	Achieved	FEM	100
3	T2	D2	List of alternative crops in some selected scenarios taking into account agronomical methods, adaptability to climate change scenarios, potential market	Achieved	ARO FEM	100
3	T2	D3	List of pest and pathogens reported on the selected alternative crops and available models for spatial and temporal dynamics of pests/pathogens on alternative crops from literature	Achieved	ARO	100
3	T2	D3	List of effective control measures and known biocontrol agents/hyperparasites of pests/pathogens of grapevine, apples, berries	Achieved	FEM ARO	100
3	T3	D1-D3	Adapted P/P physiological models to be used in the ENVIRO tool	Achieved	FEM	100
3	T3	D2	Identification of economically important P/P present in Trentino or potentially immigrating to Trentino – Drosophila suzukii (arrived), Bactroceras, Monilinia fructicola, Alternaria mali	Achieved	FEM	100
3	T4	D1	Historical data pool on P/P and quality to be used for the validation of models in ENVIRO tool	Achieved	FEM	100
3	T4	D2	List of existing and available data on pest/diseases, quality and production on grapevine, apple in Trentino (possibly at lest of the last 10 years) and validation of the ENVIRO tool	Achieved	FEM	100
3	T4	D3	Prototype tested and 1 scientific publication together with Activity 1	Achieved, Caffarra et al.,	ALL	100
3	T5	D3	At least 2 (instead of 6) implemented models for poorly investigated P/P but potentially becoming epidemic in Trentino – Rosellinia necator, Phomopsis mali,	Achieved	FEM	100

3	T5	D3	Minimum of one peer reviewed article on biology or epidemiology of P/P	Achieved, Review su Drosophila	FEM	100
3	T6	D2	Two peer reviewed articles: Identify the parameters that play a role in the model systems for studying the effect of multitrophic interaction	Pertot et al. to be submitted	FEM	80
				Pertot et al. submitted	FEM	90
3	T6	D2	Two peer reviewed articles on the effect of relevant parameters on the interactions of the multitrophic systems, (ARO, IASMA).	Achieved Pellegrini et al.	FEM	100
				Achieved Pellegrini et al.	FEM	100
3	T7	D3	One peer reviewed article on comparison of the model systems in two natural environments, how can climate influence tritrophic interactions (current alpine environment, S. Michele, and Mediterranean climate, Tel Aviv)	In preparation, Pertot et al.	FEM	80
4	A4	D3	Means to suppress P/P that are intensified with climate change	Achieved – *Lysobacter capsici PG4*, *Bacillus amyloliquefaciens* (FEM)	FEM ARO	100
4	T1	D3	Alternative agricultural systems	Achieved	ARO	100
4	T1	D3	At least two peer reviewed articles on environmentally sound means to suppress P/P	Achieved Elad et al.	ARO	100
				Achieved Borenshtein et al.	ARO	100
4	T2	D3	Scale up of prototypes, products	Achieved - 1 product (SCNB2), 1 prototype (Sentinella)	FEM	100
4	T3	D3	Prototype of a web-based platform for managing P/P control and quality under climate change; user evaluation	Achieved – Monberry Decision support system	FEM	100
4	T4	D3	Technologies that could be implemented as adaptation tools in the long term scenario, with cost/benefit and acceptance analysis	Achieved	FEM, ARO, ETH	100
5	T1	D1	list of existing and available data on temperature, rainfall quantity and distribution and on farm accountancy.	Achieved	UNITN FEM	100
5	T1	D2	list of meteorological variables that most influence yield and quality of the reference crops	Achieved	UNITN	100
5	T1	D3	new Data Base which integrates all the interesting data (spatial coordinates, meteorological variables, structural and economic data).	Achieved	UNITN	100
5	T2	D2	one peer reviewed article on the effect of climate on economic performance of homogeneous groups of farms.	De Salvo et al. accepted with minor revision	UNITN	95
5	T2	D2	the list on the most important variables influencing the economic performance of Trentino' farms.	Achieved	UNITN	100
5	T3	D3	one peer reviewed article on Analysis of farmers' perception of	Achieved, Menapace et al.	UNITN	100

			climate change and one peer reviewed article on willingness to adopt different mitigating/adapting strategies			
5	T3	D3	several bio-economic farm models for different groups of farms	Not feasible	UNITN	0
5	T4	D3	one peer reviewed article on Modelling farmers' behaviour in response to risk and uncertainty associated to climate change.	Menapace et al., submitted	UNITN	90
5	T5	D3	one peer reviewed article on the sustainability of different strategies.	Rizio et al. under preparation	UNITN	80
5	T6	D3	two peer reviewed articles, one on the results in terms of the willingness to accept or to support the different adaptation strategies, the other on the methodological issues related with the design of the choice experiment.	Achieved, Moser et al.	UNITN	100
				Achieved Cerroni et al.	UNITN	100
5	T7	D3	a peer reviewed article on the study of the potential crops that could substitute existing crop in case of extreme event and peer reviewed article on the analysis of the future impact of these new alternatives.	Paper under preparation (DEXiPM)	FEM UNITN	70

Role of external partners

During the project FEM established several collaborations. In particular a collaboration with dr. Marc Ongena, Gembloux Agrobiotech in Gembloux (Belgium) for the study of the interaction in multitrophic systems (Activity 3) and a collaboration with Tsvi Kuflik, University of Haifa, (Israel) for the development of the web-based DSS. We use the professional support of Federica Manzoli for the implementation of dissemination of results to the wide public (e-conference on the web-site and booklets). FEM also collaborated with two companies: Manica spa and R&D systems for the implementation of SCNB2 and Sentinella DSS, respectively.

During the four years of the project UNITN needed to involve some external collaborators. Some of them had a pure support role: Riccardo Scarpa for some elaborations using a Biogeme, Roberto Caparbi for the dataset from the Choice Experiments, Jacquelyn Gui Scarpa for English proof-reading, Inea for data provision. Other collaborations were considered an opportunity to interact with scholars involved in the same field of research (Greg Colson from the University of Georgia (USA), Carlo Fezzi from the University of East Anglia). We used the service of Agriduemila for the administration of the survey to a sample of farmers growing apple and vine grape, and the services of OGP for administering the computer assisted face-to-face survey to a sample of 797 taxpayers in the entire province of Trento.

3. Conclusions

FEM

This represent the first project tackling in an organized and interdisciplinary way the problem of climate change and its potential effect on plant protection in agriculture. The project implemented models, increased knowledge on the impact of climate on the pant/pathogen systems, but also on beneficial microorganisms. The results obtained by the project indicate the some systems can be strongly affected by climate, as the level of disease in a crop, however once the phenology of the plant is taken into consideration the impacts seems to be much lower. This finding highlighted the importance of taking the whole system into consideration (plant/pathogen/biocontrol agents) and not only single factors. The implementation of models in the ENVIRO give a clear picture of the future impacts and can be used for taking daily decisions or long term decisions. Several pest and pathogens could represent a risk in Trentino because of climate change. Three of them have been identified as the major concerns because their dependency of climatic conditions and the potential economic impact on Trentino crops. The project gave important knowledge on the biology of these pest/pathogens, which can be used by growers and advisors to plan suitable strategies. The project developed some tools to counteract the effect of climate change on pest/pathogens which are supposed to increase their importance in the future. These tools include biopesticides and DSS. The products have been reached a stage that allows field application. The future step will include the involvement of companies for the industrial production and commercialization. The results of the project have been disseminated via traditional media as scientific and technical journal, workshop, but also use new tools on internet. The results have been presented on a virtual conference (e-conference) which can be attended worldwide on the project web-site (www.envirochange.eu). A list of booklets for students and wide public have also been prepared and are available to be downloaded from the website. Thanks to the results and the activity of the project FEM participates as partners in two EU KBBe projects (PURE and CoFREE) and is coordinating a IAPP project with industry (INNOVA).

FBK

The ENVIRO tool represents a state of the art WebGIS prototype created to improve availability and accessibility to climate data and climate change scenarios and an effective web processing framework for scientific computing able to map the impact of climate change on agricultural systems at a compatible scale for environmental studies and policy decision. To allow scientists to reproduce their models, test and validate their simulations on different datasets and in different geographic locations ENVIRO is a first step on the path to follow to come out of the modeling black box paradigm. What is still missing is a real direct web scripting interaction between the user, the database and the geoprocessing libraries. This is due to a missing framework for online interactive geoprocessing scripting able to control the accessibility of new and implemented goeprocesses on the server. Moreover to harmonize climate data and climate models with local geographic data using different sources the multiscale factor needs to be mastered. It is a major problem if considering that climate data not only change in space but also in time. The scientific and decision making community need a framework able to resample use full data at the correct scale in space and time using different geospatial approaches and input depending on the application field and data. Real 3D spatial (x,y,z) data visualization, modeling and geoprocessing via Internet in also a major issue that came along while developing ENVIRO. A real 3D web framework able to model, manage and analise 3D spatial data is also something that need further studies. A real 3D spatial analysis library for spatial geodata is still missing.

ETH

The development of quantification method of the apple scab fungus replaces the visual scoring by an evaluator (biased) possible only after symptom appearance and hardly quantifiable. The related

publication in Plant Pathology was selected as monthly "choice of the editor". For the first time the variability of ontogenic resistance in relation to temperature could be analyzed and surprisingly the dynamic of the pathogen clearly lags behind that of the onset of ontogenic resistance, leading to the assumption that with increasing high temperature under equivalent rain pattern scab disease intensity will diminish. The fact that the sequencing costs drastically dropped allowed us to change to the whole transcriptomic analysis by RNA-seq. and, which is rather seldom, operate with three independent biological repetitions giving the resulting data a high significance. The current data base stored information was used to identify potential genes involved in ontogenic resistance. It is now possible to study each gene individually and in combination searching for ways and means to anticipate the onset of ontogenic resistance as durable scab resistance strategy. In the original project we proposed to expand the genetic analysis to three cultivars. We dropped this preferring a threefold repeat in view of publication as the novelty of the data may suggest artifacts if not sufficiently underlayed. The contamination of human food with mycotoxins is an increasing topic worldwide. Starting from the well-known problem in warmer climates we first surveyed the Trentino vineyards and were able to determine overwhelmingly the absence of OTA-mycotoxin producers. Implementing a verified prognosis program for OTA-risk and feeding it with Trentino present and future climate data (August) we confirmed the current absence of risk, however with increasing temperature scenarios an increasing real risk will appear starting from the lower part of the Adige valley. We supplemented this information with an easy to use test for OTA producing fungi present in or on grape berries. As currently no risk is present only wineries looking into the future will be interested to follow the prognosis program and implement this test. We hope that a leading winery (or FEM) will pursue this road to avoid on the long term mycotoxin contamination in Trentino wines.

ARO

Treatments that were tested in the different plant-pathogen systems included BCAs from our collection or commercially available, friendly control agents (both resistance inducers or biocides. Most of the inducers that were used in the present research are biocontrol agents that were capable in combating plant diseases and promoting plants growth under various a biotic conditions that are expected to be common as climate change develops in the future. To these agents we added an inducer that was recently developed by FEM and ARO (SCNB2) and the most recently developed means of plant health improver – the biochar. The biocontrol agents, resistance inducers and biochar are all environmentally friendly, resilient in their activity at climate change various conditions and all allow adaptation of agricultural systems to the new future conditions.

We focused on P/P, which indicate a potential high impact in the selected scenarios of Activity 1, and we developed new environmentally sound control measures and adjusted agronomic practices for the optimization of plant protection and agronomic management. A climate change reflection on the biotic and abiotic stress as well as on the control agents was described. Moreover, we studied the mode of action of the inducers and we could show an adaptation as well as mitigation role in the researched systems.

In recent years there has been a remarkable resurgence of interest worldwide in the agricultural utilization of charcoal for at least four inter-related reasons. Pyrolysis, the means by which charcoal is produced, generates renewable energy products. Many organic wastes can be treated and converted into energy via pyrolysis. When used as a soil conditioner, charcoal appears to significantly improve soil tilth, productivity, nutrient retention and availability to plants via slow-release fertilizing properties and improved water holding capacity, nutrient holding ability, and soil aggregate stability. The half-life of biochar in soil has been estimated to be hundreds to tens of thousands of years depending on feedstock and pyrolysis conditions. This leads to carbon storage in the soil and its removal from the atmosphere. Additions of biochar to soil have been found to reduce emissions of greenhouse gases.

We reported an increase in several plant growth parameters for both plants under biochar-treatment. biochar-induced plant growth stimulation goes beyond obvious contributions to plant nutrition and

improved soil physical and chemical properties. Biochar addition caused significant changes in microbial community composition and enzyme activities in both bulk soil and the rhizosphere.
The possibility that biochar induces plant systemic resistance responses against disease micro-organisms has been studied in several different systems involving foliar pathogens. Molecular evidence for systemic induction of plant defenses via both SAR (systemic acquired resistance) and ISR (induced systemic resistance) pathways by biochar was recently presented.
All in all, the inducers allowed the facing of potential disease problems in a current crop like strawberry and in a potential additional future crop like tomato under conditions of increased temperatures and other characteristics of future climate in the region.

UNITN

The analysis of the relationship between economic results of Trentino farms and climate related has demonstrated the possibility to apply the Ricardian approach at a very small geographic scale accounting on data that are easy accessible for all the European regions (Farm Accountancy Data Network FADN, the European Soil Database ESDB). As critical points we highlight that our analysis considers only irrigated farms and the impacts of the expected reduction in summer precipitation can result underestimated. Moreover, since the Ricardian approach is not apt to identify the adaptation strategies the farmers will follow, we are not able to predict if the agricultural sector in Trentino is likely to change in the midterm because of variety and/or crop switching or shift of cultivations towards higher altitude. Our results are site-specific and cannot be generalized to other contexts. Overall, the empirical evidence on farmer climate change risk perceptions provides both a positive and negative outlook for policy makers and outreach professionals to assist farmers adapt to changing agronomic conditions due to climate change. On the positive side, we find that a significant portion of farmers in our sample are not merely concerned about climate change, but are indeed forecasting increased crop damage likelihoods for the future. Moving forward with farmer assistance programs, this indicates that the largest hurdle is not educating farmers of climate change induced increases in agronomic risk probabilities, but in assisting with cost-effective methods to control or mitigate these risks. However, our empirical evidence also indicates that farmers' future beliefs are anchored by historical outcomes and personal experience. This feature, which is consistent with heuristic behavior found in many uncertain settings, poses a challenge for farmer assistance programs because it dampens the responsiveness of farmers to evolving crop risks. The survey on farmers results in several important methodological contributions. From an experimental point of view, we show the importance of the framing of gamble task experiment to elicit risk aversion in a context that is closed to the actual risky decisions (for example weather insurance purchase decisions). As a critical point, we emphasize the need to check for the validity of this result with a more diverse sample in terms of farm and farmer characteristics and different crops. From an empirical point of view, we show the applicability of subjective beliefs to obtain more accurate and reliable estimate of risk aversion. A critical point in this context is the need to check the consistency across time and farmers of the subjective beliefs elicitation mechanism. The survey on experts' climate change perceptions was pure qualitative and no statistical analysis was possible because the small number of observations. The application of DExipm tool has highlighted the possibility to use this tool for sustainability assessment of adaptation strategies. However two limits emerged: the need to collect large amount of data and the ability of common users to manage those data. These aspects limit the possibility to extend the application of Dexipm as a decision support tool for single farmers.
Moreover the application of Dexipm on a single enterprise raises the issue of not being representative of the general situation. On the other hand, the idea to apply the Dexipm to a representative sample of farms is not feasible because the two limits highlighted above. The only feasible solution appears to collect data for few farms considered representative of different types of farms. The CE on apple consumers highlights that organic production is the only sustainable production method recognized by consumers and origin plays a great role in explaining consumers choices. Agricultural mitigation practices are positively valued be consumers since positive willingness to pay for this attribute are estimated. This CE contributes to the literature in several directions: it investigate consumers preference for different sustainable production methods scarcely

addressed in the literature, it confirms the presence of hypothetical bias in CEs and it investigates the use of thresholds in fruit buying behavior. As limitation we highlight that the impossibility to pay a participation fee in the field setting (supermarket) has hindered the possibility to measure the endowment effect in real CE. The CE on pesticides risk perception is the first stated-preference study which incorporates subjective risks into the design of choice experiment. A limitation of this studies is that the composition of our treatments were subjects face risk levels that differ from their expectations depends on their risk priors. Unfortunately, this procedure may have affected the composition of these subsamples which, in this study, should be similar across treatment groups, as key socioeconomic variables likely affect willingness to pay for R&D programs. Fortunately, having data on these variables allows control via additional econometric modeling.

Possible future development and continuation of the activities by the Partners/illustrare le concrete prospettive di sviluppo e continuazione dell'attività di ricerca all'interno degli enti partecipanti

FEM
FEM will continue the activity of developing the biopesticides within the EU project PURE, CoFRE and INNOVA. Modeling of *D. suzukii* will be continued.

FBK
The use of a WebGIS for the integration and armonization of pre- existing models, climate change and axillary climate data, impacts studies was focused on a standalone and open source geospatial data processing routines, giving a good result and precious technical indications for future development. In this exploratory analysis the focus was on Trentino province and two main agricultural systems for the research area. ENVIRO is anyhow a scalable tool and could be extended to the Alpine region or to other research contests and applications as for example hydrology, forestry, ecology, entomology etc. becoming a central repository for spatial data and spatial model that take advantages of climate change scenarios at regional scale.
A concrete proposal to continue the development and the engineering of the ENVIRO prototype together with CAVIT was strongly suggested by FBK, FEM and CAVIT in the last year of the project. A steady stream of data over time is of fundamental importance for the monitoring of biological phenomena and the agricultural production. Much of the data streams and weather forecast algorithms in the province of Trento do not have jet a real application management tool accessible through the Internet and able to implement and display on a map weather driven environmental models. In particular, there is a need to provide, through a central system, tools to support agricultural decision making taking advantage on the rich availability of weather data and weather forecasts.
The new platform will provide concrete tools for strategic and tactical management decisions related to the area of wine production as for example

1. New space-time tools to guide the production based on real weather data and market demands
2. An integrated data-harmonized calculation processes GIS dedicated to wine production
3. A new system to support decision making in space and time
4. Continuous improvement of the methods of extraction and connection between environmental data (eg sensors) and analysis of products (laboratory, field laboratory)
5. Architectures designed to take decisions in the field using mobile devices

ETH
do the retirement of Prof Gessler will not continue any activity, however all expertise gained in this project will be made available to FEM-FEM.

ARO
In the present research we laid the basis for the implementation of biochar as a means to suppress plant diseases. There are various aspects that were not developed enough. Aspects of using biochar

as a soil conditioner and as a tool for capturing greenhouse gases has to be promoted and developed on a large scale. Only large volume of biochar production and soil application will be able to significantly contribute to mitigate climate change factors. Yet, this is probably out of the scope of the current and future research that is continuing on the present line. Biochar as a means of adaptation of agricultural systems to biotic stresses was demonstrated in the present project and we intend to further develop it. We already started with some steps on various directions that will lead to understand the details of use of biochar according to lines of broader biotic targets, effect on abiotic stresses, possible drawbacks of biochar incorporation into soil. We will study the differences in the biomass source that is fed to the pyrolysis process – is there a difference in efficacy of the different biochars. What are the better conditions (temperatures) for biochar production that end in better induction of disease resistance? We focused until now on a narrow range of foliar pathogens, two soilborne diseases and a limited range of plant hosts. There is a need to test the biochar against more diseases, especially soil borne ones and on some plant hosts that are agriculturally important. At present the effect of biochar on pests is not clear at all and should be elucidated. An important step forward in biochar research is the larger scale experience with it. Field conditions experiments are crucial for its future development as a tool to be used in agriculture. Some researchers have already tested biochar under field conditions but usually in extensive farming and not usually for testing crop protection. We started testing several biochar types in commercial like greenhouse conditions in order to test effect on plant health and plant productivity in an intensive cropping system. Other aspects that should be tested are the compatibility of the various inducers with commonly used practices in the relevant crops. For instance the combination with other pesticides is not tested enough and an additive effect is hoped for. A special case is the combination of biochar with pesticides. There is a new trend of pesticides application into soil for suppression of soilborne and foliar problems. Biochar had a large surface area and it may absorb chemicals in soil as well as act as a slow release agent. The effect of biochar on soil applied pesticides needs to be clarified and guidelines for its use need to be developed.

UNITN

The research on farmer decision whether to purchase an insurance will continue in cooperation to ISMEA (Roma) which is responsible for the Italian data bank on risk in agriculture. We are going to investigate the possible matching between stated preference data with actual behavior of farmers.

The expertise gained with the two CEs carried out during the Envirochange project will help us to design new innovative Choice experiments. The inclusion of the Exchangability Method for subjective probability elicitation in the CE emerged to be very stimulating and will surely used in other context involving risk perception.

4. Validation of results from 01/09/2008 to 31/08/2012:

Dissemination for the wide public worldwide
A final e-conference presenting the major project results was prepared and it is available on the project website (www.envirochange.eu).

A list of bookets to be used by students and wide public have been published on the website

15. Enviro: a platform to map and study the effects of climate change on agriculture at very high resolution Riccardo De Filippi
16. Climate change and agriculture Emanuele Eccel
17. Climate change impact on plant pathogens and plant disease Ilaria Pertot and Yigal Elad
18. Climate change and plant pathogens. The case of two grapevine diseases Amelia Caffarra
19. Genomics to plant health: Effect of climate change on plant Michele Perazzolli , Maria Cristina Palmieri, Benedetta Roatti, Gerardo Puopolo, and Ilaria Pertot
20. Climate change and the risk of ochratoxin contamination – Present and future of Black Aspergilli in Trentino grapes Michelangelo Storari
21. Climate change and ontogenic resistance Michele Gusberti
22. *Drosophila Suzukii:* a new invasive species threatening European fruit production Gianfranco Anfora

23. *Rosellinia necatrix*: an increasing problem in replanting of apple orchards Sandro Pastorelli
24. Alternative tools in agriculture Dario Angeli, Alberto Pellegrini, and Oscar Giovannini
25. Climate change and possible impacts on soil Paola Elisa Corneo, Noemi Herrero Asensio, Claudia Longa, Alberto Pellegrini, Michele Perazzolli, and Ilaria Pertot
26. The biochar effect: plant resistance to biotic stress Yigal Elad and Ellen Graber
27. How many bad apples are in a bunch? An experimental investigation of perceived pesticide residue risks Simone Cerroni, Sandra Notaro and W. Douglass Shaw
28. Risk aversion, subjective beliefs, cognitive heuristics and farmers' perceptions of risks related to climate change Luisa Menapace, Gregory Colson, Roberta Raffaelli

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Project Title: GIS and Machine Learning in precision agriculture (Local)
It is a local project together with Cantina Colli Mori Zugna (CMCZ) with objective to define a pre harvest sampling method with to optimize the quality and diversification of the final product Experimental phase from 2010 to 2012. Using maps from meteorological variables and insolation coming ENVIRO spatial temporal database (enviDB) a set of algorithms able to calculate bioclimatic indexes at for high spatial and temporal resolution for the calculate a for all Chardonnay parcels of the CMCZ a set. Once calculated, methods for clustering time series were used to identify groups of particles with the same maturity profile. Validation of vine parcel groups was done in the following harvesting season. To sustain the requests for large calculations on climatic data, the scientific computing environment was based on high performance computing methods (GPGPU and Cloud Computing).
Project Title: WebAtlanteClimaticoTrentino (Local)
In collaboration with the local climate observatory FBK was involved to develop the WebGIS for the Atlante Climatico Trentino. The objective of the project is the development of a WebGIS prototype to be included as a module in the portal www.climatrentino.it where all climate data and maps framed in the ENVIROCHANGE spatial temporal database (enviDB) are collected and make accessible, via a web mapping interface. Using enviDB as centralized geodatabase the system can provide climate maps and high-resolution climatic indexes of the main variables of interest in the form of web report.
CLITRE.50 (L, climate processing of 50-year series in Trentino) – exp. May 2012
CLITRE.100 (L, climate processing of secular series in Trentino, climate projections. In collaboration with ARPA Emilia – Romagna, Bologna) exp. June 2013
EU Project PURE
EU Project CoFREE

xiv)Patents/Brevetti[2]

No patents

xv) Partecipation to projects not funded by PAT on similar subjects/Partecipazioni a progetti non finanziati dalla Provincia sulle tematiche oggetto della presente ricerca;

No Participation

xvi) New equipement, database, exprimental set up methods, etc./Realizzazione di nuova strumentazione, set-up sperimentali, strumenti informatici, banche dati ecc.;

xvii) Results and products (quantifiable)/Risultati e prodotti ottenuti

xviii)Other/Altro

R-libraries publicly available in R-Cran repository:
Cordano, E., and Eccel, E.: RMAWGEN: Simulations of future weather scenarios with a stochastic Monte-Carlo generator (http://cran.rproject.org/web/packages/RMAWGEN/)
E. Eccel and E. Cordano: Interpol.T: hourly interpolation of daily minimum and maximum temperature series. Available on R-cran http://cran.r-project.org

[2] Precisare la parte di proprietà della Provincia.

5. Education/Formazione alla ricerca

The project conducted an annual training camp for all its collaborators during the annual meeting. As the project assembles a vast array of disciplines (plant protection, plant genetics, economy, climatology, etc.), each participant group of the project taught the basics necessary to understand the project and the outputs to all participants. In the restricted area of the web-site we put training material, handbooks, methodologies used during the project.
The collaborators were pushed to present their results in workshop and conferences (with a minimum target average of 0.5 oral-poster presentation/year per collaborator.

Two edition of WebValley FBK summer school, where organized jointly with the ENVIROCHANGE project. The school aims to create a team of enthusiastic and motivated high school students (18 y), working in a lively and interactive atmosphere together with a group of MYTRA researchers and international experts. In three weeks, the team develop a web-based prototype for managing and analysing climate change data. Students are introduced to Open Source software solutions (scientific programming, interfaces, database, data modelling); they discuss, design and develop the new system interacting with scientists in a high-tech lab. More than 250 students have attended the WebValley camps since its first edition in 2001. Started as a regional initiative, since 2010 is affiliated to the INTEL ISEF, the most important science fair in the world.
Specifically, WebValley 2010 aimed at building the GeoScalerHub web platform, implemented as an Open Source software which quickly configures internet resources for climate change studies at regional scale with global geospatial and statistical indicators available from international agencies. The platform has been further developed in 2011, in collaboration with MUSE Trento, WebValley, providing a Web-Kinect-GIS interface to climate change scenarios and complex environmental data. The project combined the Kinect controller with GeoScalerHub to explore new ways to interact with geospatial patterns, also devising downscale methods to quantify the need for adaptation strategies using climate change scenarios at local scales.

The UNITN research group organized in 2010 an international workshop on “RISK ELICITATION AND STATED PREFERENCE METHODS FOR CLIMATE CHANGE RESEARCH” in order to discuss the latest advance in risk elicitation techniques and to gain useful insights for designing the choice experiment on the Trentino population (task 6).

1. Dates	21-22 OCTOBER 2010
2. Duration	2 days
3. Title	RISK ELICITATION AND STATED PREFERENCE METHODS FOR CLIMATE CHANGE RESEARCH
4. Name and type of organisation	Dipartimento di Economia
5. Where	Trento, Sala Conferenze della Facoltà di Economia
6. Participants	35

Partner	Name	Surname	Degree (master, PhD student, post-doc	Training program, Acquired skills
FEM	Benedetta	Roatti	PhD student	PhD courses at ETH Zurich
FEM	Monica	Rinaldi	PhD student	PhD courses at the university of Piacenza
FEM	Bahcine	Ezzahi	Master	Master course at IAM Bari
FEM	Houda	Banani	Master	Master course at IAM Bari
FEM	Shuhub	Alani	Maser	Master course at IAM Bari
FBK	Shamar	Droghetti	Technician	Code sprint on WPS at the FOSS4G 2009 Sydney.
FBK	Shamar	Droghetti	technician	Workshop in advanced Open Layer. WebGIS interface
FBK	Riccardo	De Filippi	Researcher	Creazione servizi web geografici.
ARO	Ohad	Agra	Master student	M. Sc. Training program (research thesis and university courses), Hebrew University of Jerusalem – Faculty of Agriculture at Rehovot Israel, 2.5 years, Acquired: microbiology, mycology, botany and phytopathology research skills
ARO	Hananel	Ben Kalifa	Master student	M. Sc. Training program (research thesis and university courses), Hebrew University of Jerusalem – Faculty of Agriculture at Rehovot Israel, 2.5 years, Acquired: microbiology, mycology, botany and phytopathology research skills
ARO	Zaraye	Mehari Haile	Master student	M. Sc. Training program (research thesis), Hebrew University of Jerusalem – Faculty of Agriculture at Rehovot Israel, 1 year, Acquired: microbiology, mycology, botany and phytopathology research skills
ARO	Amit	Kumar Jaiswal	Master student	M. Sc. Training program (research thesis), Hebrew University of Jerusalem – Faculty of Agriculture at Rehovot Israel, 1 year, Acquired: microbiology, mycology, botany and phytopathology research skills
ARO	Hellen	Quinonez	Master student	M. Sc. Training program, Hebrew University of Jerusalem – Faculty of Agriculture at Rehovot Israel, 6 months, Acquired: microbiology, mycology, botany and phytopathology research skills
ETH	Storari	Michelangelo	PhD student,	Acquisition of social and general professional skills as required in the Ph.D program of ETH 1.
ETH	Gusberti	Michele	PhD student	Acquisition of social and general professional skills as required in the Ph.D program of ETH
UNITN	Riccarda	Moser	PhD student,	PhD training program at University of Trento, Winter School on “System Analysis and Integrated Modelling in Climate Change Research, Venice, February 3-6 2009; International Choice Modelling Conference, Harrogate (UK) , March 30 –

				April 1 2009; International Summer School on “Discrete Choice Models -Theory and Applications to Environment, Landscape, Transportation and Marketing” Bologna, June 29 - July 3 2009; Course in Evaluating CAP by PMP Tools: Introduction and Practice, Parma, 5-9 October 2009; International Workshop on "The Social Dimension of Adaptation to Climate Change; Venezia 18-19 February 2010. Acquired skills: choice experiment design and discrete choice data analysis; positive mathematical programming
UNITN	Simone	Cerroni	PhD student,	PhD training program at University of Trento, visiting scholar at Texas University, The International Summer School on “Discrete Choice Models - Theory and Applications to Environment, Landscape, Transportation and Marketing” Bologna, June 29 - July 3 2009,; Training Course on Choice Modelling, Vila Real, Portugal 31 August - 3 September 2009; International Summer School: Advances in Discrete Choice Models and Experimental Design for Stated Choice Venice, 27 September - 1 October 2010; Experimental Auctions: Theory and Applications in Marketing and Consumer Preferences Analysis, Bertinoro 04 – 12 July 2011. Acquired skills: choice experiment design and discrete choice data analysis
UNITN	Maria	De Salvo	Post-doc	Participation to EAERE 18th annual conference, Roma, June 2010, Belpasso International Summer School on Environmental and Resources Economics 4-11 September 2011 Acquired skills: expertise in Ricardian model application and estimations
UNITN	Luisa	Menapace	Post-doc	First Joint EAAE / AAEA seminar, 115th EAAE Seminar "The Economics of Food, Food Choice and Health, Freising 14-17 Septermber 2010; International Research Seminars: the Theory & Practice of Experimental design for stated choice data, Trento, 29 October 1 November 2010; International Choice Modelling Conference, Leeds, July 2011; Forum Internazionale AS.NA.CO.DI Workshop on "Gestione dei rischi e delle crisi in agricoltura Politiche nazionali e Politica Agricola Comunitaria dopo il 2013, Roma 18-20 November 2011; International Choice Modelling Conference Leeds 04/07/2011 to 06/07/2011. Acquired skills: risk perception elicitation techniques and choice experiments design and discrete choice analysis elaboration
UNITN	Massimiliano	Cortelletti	Master	Master Thesis on experts’ perceptions on

			student	climate change and adaptation strategies. Acquired skills: survey design and administration
UNITN	Cristina	Cadrobbi	Borsista	Research assistant; Acquired skills: survey respondents recruitment and survey administration