EFSA's environmental risk assessment of the apple snail for the EU: a novel approach

Sybren Vos
European Food Safety Authority, Animal and Plant Health Unit / Plant Health Team, Italy

Sara Pasquali
CNR-IMATI, Milano, Italy

Gianni Gilioli
University of Brescia, School of Medicine, Department of Molecular and Translational Medicine, Italy

Nils Carlsson
The County Administrative Board, Environmental Department, Sweden

Pablo Rafael Martín
Laboratorio de Ecología, INBIOSUR (Universidad Nacional del Sur-CONICET), Bahía Blanca, Argentina

Gritta Schrader
Julius Kuehn Institute, Federal Research Centre for Cultivated Plants and Institute for National and International Plant Health, Braunschweig, Germany

Introduction

In the context of a pest risk assessment, the potential consequences caused by a harmful organism needs to be estimated including the environmental consequences, besides the evaluation of other risk components. This publication describes a novel approach that was developed by the Panel on Plant Health (Panel) of the European Food Safety Authority (EFSA) and used to perform the environmental risk assessment for the apple snails for the EU.

Apple snails are considered to be serious rice pests and can cause devastating effects on the flora and fauna of natural wetlands. In 2010 the Island apple snail, Pomacea maculata, started its invasion in the rice fields in the Ebro Delta in Spain where it is currently still spreading. Today, the snail is not only present in rice paddies but also in some nearby wetlands, and it has been found moving upwards along the Ebro riverbeds.

In 2012, on the request of the European Commission, the EFSA Panel on Plant Health (Panel) evaluated a Spanish pest risk analysis on the apple snail (Spanish Ministry of Environment and Rural and Marine Affairs, 2011) and concluded that the risk posed by the apple snail to the natural environment was not sufficiently addressed and recommended that further study should be performed. Consequently the Panel was requested by EFSA to perform an environmental risk assessment on the apple snail for the EU.

The snail population density was identified as the driver of the ecosystem change, and therefore the factor playing the major role in determining the impact of the snail on the environment. The Panel developed a population dynamics model to estimate the potential population densities of snail eggs, juveniles and adults, and to identify the potential snail hot spots in Europe. As a result maps were generated to represent the potential snail density distribution in the EU territory (EFSA PLH Panel, 2013).

The environmental risk assessment procedure developed by the Panel and presented in its guidance document (EFSA Panel on Plant Health, 2011) was used to assess the negative impact of the snail invasion on the shallow freshwater areas containing macrophytes such as wetlands, shallow lakes, river deltas and the littoral zone of deeper lakes and rivers in Europe (EFSA PLH Panel, 2014).

This work has been published in two scientific opinions[1] by the EFSA Panel on Plant Health and the key aspects from these scientific opinions are presented in this paper.

Potential establishment of the apple snail in the EU

A brief summary of the key biological features of the apple snail that were considered in the population dynamics model used to assess the potential establishment of the apple snail in the EU is presented.

Brief summary of the biology of the apple snail

Apple snails are tropical and sub-tropical freshwater snails from the family Ampullariidae (Mollusca: Gasteropoda). Within the genus Pomacea, the difficulty to differentiate the species P. canaliculata and P. maculata on the basis of their morphological characteristics is recognised by many authors (Cowie and Hayes, 2005; Cowie et al., 2006). Hayes et al. (2012) provides a clarification on the taxonomy, describing their morphological and genetically based diagnostics, and re-evaluating their biogeographic ranges showing that the two species differ mostly genetically. Figure 1 shows a picture of an adult golden apple snail.

Figure 7
Adult golden apple snail – *Pomacea canaliculata*

Source: by courtesy of Nils Carlsson

Both snail species are highly invasive outside their native area of distribution in South America (Cowie, 2002). The invasiveness of these snails can be explained by their main biological characteristics.

The apple snails are polyphagous, they have a very broad diet which consists mainly of aquatic plants, including a wide range of plant species both cultivated and wild species, but also periphyton (algae, small crustaceans and other sessile organisms that are attached to rocks, submerged wood and the sediment), detritus and fish and snail eggs. Their broad diet allow the snails to remain at high densities even when aquatic plants resources are depleted (Carlsson et al., 2004).

[1] EFSA PLH Panel (EFSA Panel on Plant Health), 2013. Scientific opinion on the assessment of the potential establishment of the apple snail in the EU. EFSA Journal 2013;11(12):3487, 49 pp. doi:10.2903/j.efsa.2013.3487. Available online: www.efsa.europa.eu/efsajournal
EFSA PLH Panel (EFSA Plant Health Panel), 2014. Scientific Opinion on the environmental risk assessment of the apple snail for the EU. EFSA Journal 2014;12(4):3641, 97 pp. doi:10.2903/j.efsa.2014.3641. Available online: www.efsa.europa.eu/efsajournal

They have a high reproductive rate, apple snails have separate sexes (Halwart, 1994), and the female in favourable conditions is able to lay a number of egg batches, each of several hundred eggs, every week, for a long reproductive period. The females are able to store sperms after copulation for 140 days (in P. canaliculata) which can be used to fertilise series of egg batches in the absence of a male (Estebenet and Cazzaniga, 1992; Estebenet and Pizani, 1999). The total fecundity can be very high as illustrated by several authors: Estebenet and Martín (2002) estimated more than four thousand eggs laid per female and per year distributed in 8-57 egg masses; Liu et al. (2012) recorded egg masses containing 42 to around 880 eggs, with the females laying 1-15 egg masses after one copulation.

They can survive extreme conditions, being amphibious, using both gills and lungs, and can survive in poorly oxygenated waters. When threatened by predators, the snails can hide in their shell closing the operculum as an efficient protection mechanisms. The snails also use this physical protection to hibernate buried in the mud within the moisture enclosed in their shells for periods of several months when their habitat dries out (Oya et al., 1987).

In the tropical climates the average lifespan is approximately 1 year. Whereas, in subtropical and temperate climates, the snail's feeding and reproduction is reported as seasonal with a lifespan up to 3–4 years (Estebenet and Martín, 2002; Seuffert et al., 2010).

Population dynamics model of Pomacea canaliculata

A population dynamics model was developed by the Panel in a first step to represent the potential distribution of the apple snail in Europe and to derive the spatio-temporal distribution of the potential snail density to support the environmental risk assessment.

Considering the similarities between the two species P. canaliculata and *P. maculata* and considering that in the literature very few studies were performed on P. maculata, the population dynamics model was developed using mainly data and measurements from experiments performed on *P. canaliculata*.

In order to determine the spatial and temporal pattern of the environmental impact of the invasive species, its population density and its spatial and temporal variation has to be estimated. The Panel used the snail density to describe and predict the effect of the trophic interaction between the snail and the host plant community. This effect is to be considered to understand the ecosystem disturbance produced by the invasive species.

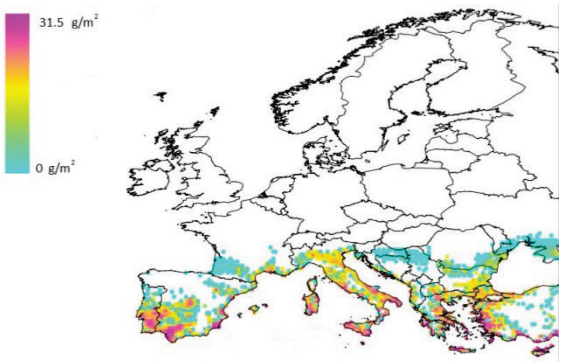
The density of the apple snail in terms of snail biomass was identified as the driver of the ecosystem change and was used to assess the effect of the snail on the environment. As for other poikilotherm organisms, the temperature is the main driver of the snails physiology. To assess the invasive snail's potential establishment in terms of potential density distribution in Europe, the Panel developed a temperature-dependent physiologically-based demographic model (PBDM).

Considering that the juvenile and adult stages preferably live in the water, a specific model was used to estimate the water temperatures starting from data on air temperature. The model is presented in EFSA PLH Panel (2013).

The population dynamics model takes into account the complexity of the life-cycle. Three developmental stages were used: eggs; juvenile and reproductive adults (male and females). Following a thorough review of the literature the Panel estimated the stage-specific parameters to define the three biodemographic functions for P. canaliculata (i.e., survival, development and fecundity rate functions) (EFSA PLH Panel, 2013). Population dynamics were described by a Kolmogorov equation (Di Cola et al., 1999) discretised with a time step of one hour for each point of the spatial grid covering the whole Europe. The dimension of the cell in this grid is 25 × 25 kilometres for Europe. The simulated snail density in each node was obtained using the specific climatic condition of the node. The potential distribution of P. canaliculata in Europe was obtained by calculating the average snail density per year for each node of the grid covering Europe. (For further details on the model and data, see EFSA PLH Panel (2013)). Owing to their trophic activity, only juvenile and adult stages are represented in figure 2.

The Panel defined the potential snail biomass as the biomass in a given point of the simulation grid where a suitable habitat is present at a time t. The potential snail biomass expressed in g/m2 depends only on climatic factors.

Figure 2
Distribution of total potential biomass (g/m²) of Pomacea canaliculata (juveniles + adults) across Europe



The colour code in the legend corresponds to biomass values, and the minimum value is above 0 (EFSA PLH Panel, 2014)

The area of potential establishment in Europe of Pomacea, comprises wetlands of southern Europe (i.e. Spain, southern France, most of Italy and Greece) and the Balkans up to the latitude of the Danube river. (EFSA PLH Panel, 2013).

Environmental risk assessment of the apple snail in the EU

The PLH Panel's environmental risk assessment of the apple snail for the EU (EFSA PLH Panel, 2014) was performed following the guiding principles presented in the Panel's ERA framework (EFSA PLH Panel, 2011). The procedure is based on scenario analysis and was performed in 4 steps: (i) in order to assess the impact of the snail on the ecosystem services, the unit of assessment, here defined as Service Providing Unit (SPU), a functional unit whose components (individuals, species or communities) are characterised by functional traits defining their ecological role (Vanderwalle et al., 2008); (ii) definition of the scales for the assessment (temporal horizon, spatial scale and biomass scale); (iii) assessment of the limiting factors (considering the impact of the potential biomass of the resistance and resilience of the receiving environment and management options), and; (iv) identification of the ecosystem traits-services and traits-biodiversity relationships potentially affected by the activity of the snail.

Three different assessments were performed by the Panel: (i) the effect of the snail biomass on ecosystem traits; (ii) the impact of the snail invasion on the ecosystem services, and; (iii) the impact of the snail invasion on components of the biodiversity. The different assessments were performed based on expert judgements that were collected by the Panel through an expert elicitation process that is presented in details in EFSA PLH Panel (2014).

The scenario analysis

A single SPU was defined i.e. shallow fresh water areas containing macrophytes such as wetlands, shallow lakes, river deltas and the littoral zone of deeper lakes and rivers. The interaction between the SPU and cultivated areas (rice fields) is taken into account.

The assessment was performed for two time horizons: (i) 5 years after establishment when the snail population density has reached its potential maximum level, and population dynamics is mainly influenced by the resistance of the receiving environment; and (ii) 30 years after establishment when the resilience of the environment plays a major role.

The area of potential establishment was predicted by the population dynamics model and expressed in terms of distribution of potential snail biomass (Figure 2).

The Panel considered three mechanisms limiting the potential biomass of the pest, the resistance and resilience of the receiving environment and management options for controlling the apple snail. As presented in EFSA PLH Panel (2014) the resistance is related to the 'force' the ecosystem opposes to the establishment process resulting from arrival or spread (e.g., quality and availability of host plants limiting the possibility to build up a local population).

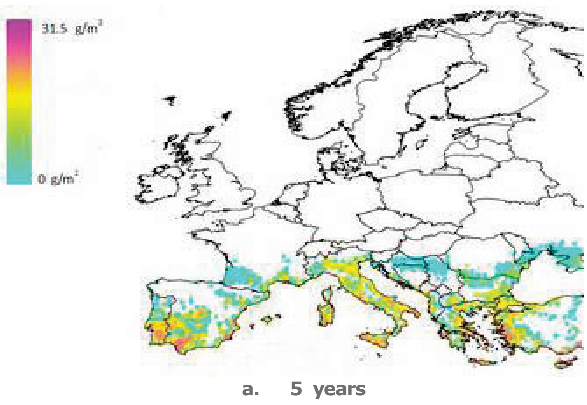
The resilience is defined as the capacity of the ecosystem to control the driving force and restore conditions similar to the ones existing before the perturbation (e.g., the action of the community of natural enemies regulating the pest population abundance). The management consists of options to reduce and manage apple snail populations. Several were presented in the Spanish pest risk analysis (Spanish Ministry of Environment and Rural and Marine Affairs, 2011), and were discussed in EFSA PLH Panel (2012). Only some of these options are expected to have serious negative environmental effects on the wetlands. In particular this is the case of (1) keeping rice paddies dry for long periods, (2) burning vegetation and river bank conditioning and (3) treating rice paddies and/or irrigation canals with (a) lime, (b) saline water, (c) snail attractants containing methaldehyde or (d) saponins.

Expert judgement was used to provide estimates of the scaling factors representing the effects of resistance, resilience and management on the potential snail biomass. They are coefficients ranging from 1 (no effect) to 0 (max effects) multiplying the potential snail biomass to obtain the realized biomass. Further details on the method used to collect the expert judgments and the values of the scaling factors are presented in EFSA PLH Panel (2014). The realized snail biomass is the expected snail biomass in a given point of the simulation grid where a suitable habitat is present at time t considering the effects of limiting factors. To estimate the realized snail biomass, the Panel used the estimate of the potential snail biomass applying the limiting factors in the two time horizons (5 years and 30 years after establishment). Consequently two maps were generated (Figure 3a and 3b) to represent the realized biomass in Europe.

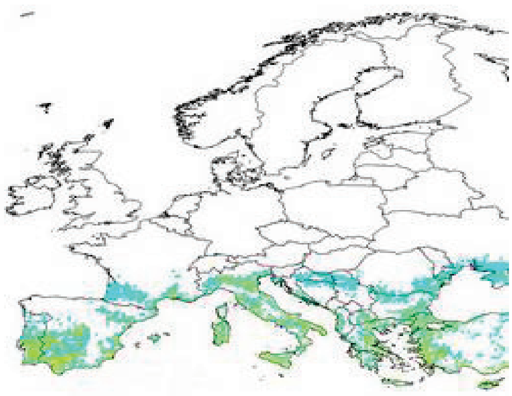
Figure 3

Distribution of average realized biomass (g/m²) of *Pomacea canaliculata* juveniles + adults over Europe

Estimations obtained by multiplying the potential biomass by the values of the scaling factors (resistance, resilience, management) estimated for two time horizons: (a) average realized biomass after 5 years; (b) average realized biomass after 30 years. (Extracted from EFSA PLH Panel (2014)).



a. 5 years



b. 30 years

The average realized snail biomass after 30 years is lower than after 5 years, because it is expected that (i) macrophytes non-palatable for Pomacea will replace the largely disappeared palatable macrophytes, and (ii) natural enemies may reduce Pomacea numbers more efficiently at the longer time horizon. (EFSA PLH Panel, 2014).

Effect of snail biomass on ecosystem traits

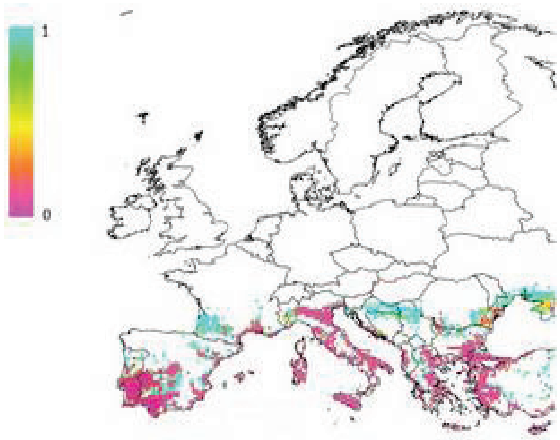
In the scientific opinion EFSA PLH Panel (2014) the Panel assessed the effect of the realized snail biomass on a set of the ecosystem traits (the complete list is presented in table 2). In a first step the relationships between snail biomass and ecosystem traits in the service providing unit were identified. Then the impact was evaluated in terms of change of the level of the ecosystem trait due to the increase of snail biomass by means of a procedure based on the collection of expert judgement. The uncertainty associated with each trait–biomass relationship was not assessed. Finally the Panel mapped the expected impact in Europe of the invasive snail on some ecosystem traits. An example is presented in figure 4.

Table 2
List of the ecosystem traits assessed by the Panel in EFSA PLH Panel (2014)

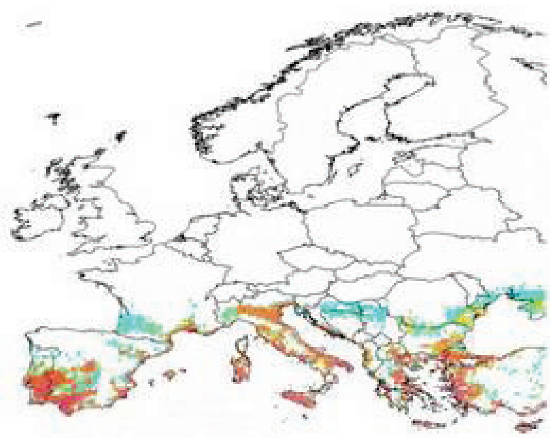
Traits assessed for impact relationship with snail biomass		
Traits related to the macrophytes	**Traits related to water quality**	**Traits related to biodiversity**
Edible macrophyte biomass	Oxygen concentration	Aquatic invertebrates biodiversity
Biomass of non-edible macrophytes	Phosphorous concentration	Amphibian biodiversity
Dominance (macrophytes/phytoplankton	Sedimentation rate	Fish biodiversity
Macrophyte species diversity	pH (percentage of variation)	Bird biodiversity
Structural complexity of the habitat	Denitrification	Zooplankton biodiversity
		Zooplankton biomass
		Periphyton biomass

Figure 4
Example of a representation of the spatial distribution in Europe of the effect of the snail invasion on the edible plant biomass extracted from EFSA PLH Panel (2014)

Distribution of the index I_ET representing the change in the edible plant biomass due to the effects of the realized snail biomass at the two time horizons. Values of the index close to zero correspond to high impact on the ecosystem trait, while values of the index close to 1 denote a low impact: (a) 5 years, short term; (b) 30 years, long term.



a. 5 years



b. 30 years

Impact of the snail invasion on the ecosystem services and biodiversity components

The impacts and associated uncertainties were estimated by the Panel through expert elicitation for each ecosystem service and biodiversity component. Each expert provided an estimate of the probability distribution of the percentage of reduction in ecosystem service provision and in biodiversity for the defined service providing unit. Five categories of reduction were considered for both the ecosystem services and the biodiversity components (see Table 3).

The assessment was performed for the maximum realized biomass (the worst case scenario) in the short and long term This methodology is presented in details in EFSA PLH Panel (2014) and the rating system used is similar to the one described in the PLH Panel guidance document on the environmental risk assessment of plant pest (EFSA PLH Panel, 2011). The rating system developed by the Panel in EFSA PLH Panel (2011) and adjusted in EFSA PLH Panel (2014) is based on a probabilistic approach ensuring consistency and transparency of the assessment. In addition a method was developed for the quantification of uncertainties that are categorised as low, medium or high.

Table 3
Rating system used in EFSA PLH Panel, 2014 for assessing the impact of an apple snail invasion on ecosystem services and biodiversity components

Magnitude class	***% reduction***
1. Minimal	Zero or negligible loss
2. Minor	0<M=5%
3. Moderate	5<M=20%
4. Major	20<M=50%
5. Massive	M>50%

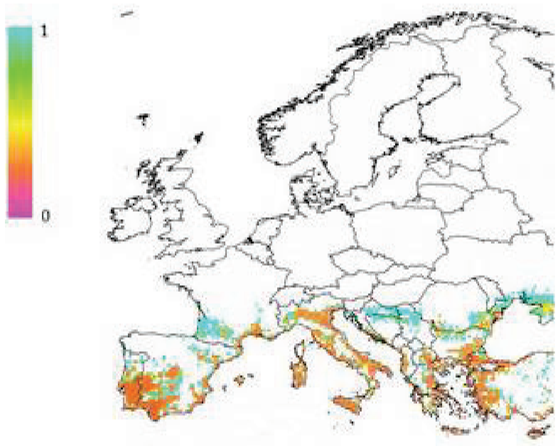
This methodology was applied by the Panel to assess the ecosystem services and biodiversity components listed in Table 4. Finally the Panel mapped the impact in Europe of the invasive snail on some biodiversity components. An example is presented in figure 5.

Table 4
List of ecosystem services and biodiversity components assessed in EFSA PLH Panel (2014)

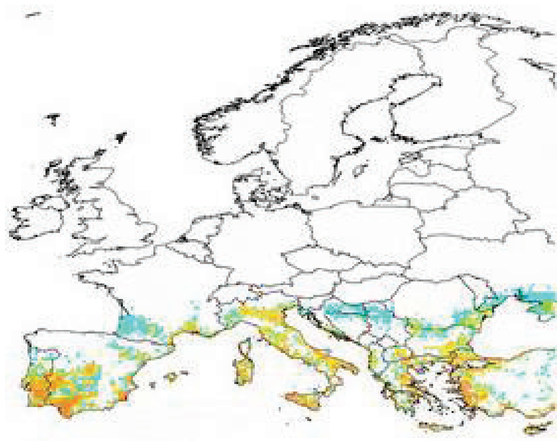
Ecosystem services assessed for impact of snail invasion		**Biodiversity components assessed for impact of snail invasion**
Provisioning services	**Regulating and supporting services**	
Food	Climate regulation	Genetic diversity
Genetic resources	Water regulation/cycling /purification	Native species diversity
Fresh water	Erosion regulation	Native habitats, communities and/or ecosystems diversity
	Nutrient cycling	Threatened species
	Photosynthesis and primary production	Habitats or other ecological entities of high conservation value
	Pest and disease regulation	
	Pollination	

Figure 5
Example of a representation of the spatial distribution in Europe of the effect of the snail invasion in Europe on the threatened species extracted from EFSA PLH Panel (2014)

Distribution of the index I_ET representing the change in threatened species due to the effects of the realized snail biomass in the two time horizons. Values of the index close to zero correspond to high impact on the ecosystem trait, values of the index close to 1 denote a low impact: (a) 5 years, short term; (b) 30 years, long term.



a. 5 years



b. 30 years

Conclusions

Following the development of the apple snail population dynamics model and the environmental risk assessment for the apple snail in the EU the EFSA PLH Panel concluded that:

- The area of potential establishment in Europe of Pomacea, comprises wetlands of southern Europe (i.e. Spain, southern France, most of Italy and

- Greece) and the Balkans up to the latitude of the Danube river. (EFSA PLH Panel, 2013).

- The average realized snail biomass after 30 years is lower than after 5 years, because it is expected that (i) macrophytes non-palatable for Pomacea will replace the largely disappeared palatable macrophytes, and (ii) natural enemies may reduce Pomacea numbers more efficiently at the longer time horizon. (EFSA PLH Panel, 2014).

- Regarding the potential impact of the apple snail on the ecosystem services, the Panel concluded that the apple snail invasion represents a moderate risk for genetic resources, climate regulation, pest and disease regulation and pollination in both the short and the long term. The Panel estimated the risk for food as moderate in the short term and major in the long term, while the risk for water regulation and erosion regulation is major in both the short and the long term. The risk for fresh water is assessed as massive in both the short and the long term and the risk for nutrient cycling and photosynthesis and primary production of macrophytes was assessed as massive in the short term and major in the long term. The uncertainty is medium for all the ecosystem services in the short term, except for erosion regulation, for which uncertainty is high in the short term. Water regulation, erosion regulation and pest and disease regulation have high uncertainty in the long term, while all the other ecosystem services have medium uncertainty in the long term. In the worst case scenario (maximum realized snail biomass), the overall effect of the snail invasion on the shallow freshwater wetlands of southern Europe is major on the ecosystem services both in the short and in the long term.

- Regarding the potential impact of the apple snail on the biodiversity components, the Panel concluded that the apple snail invasion represents a major risk for genetic diversity and native species diversity in both the short and the long term. For native habitat, the short term risk was estimated as massive and the long term risk as major. For threatened species and habitat of high conservation value, in both the short and the long term the risk was assessed as massive. The uncertainty is low for habitat of high conservation values in the long term and medium in the short term. For all the others biodiversity components the uncertainty is medium for both the short and the long term. In the worst case scenario, the overall effect of the snail invasion on the shallow freshwater wetlands of southern Europe is massive on the biodiversity in the short term and major in the long term.

- The overall risk estimated for biodiversity is higher than the one for ecosystem services, both in the short and in the long term. This could be explained by the fact that in natural environments the biodiversity components are more sensitive to perturbations and that the ecosystem services are based on functional components and are able to reduce the impact.

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MoU
between CIHEAM and the Center for Mediterranean Integration (CMI)

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On June 17, 2015, in Paris, the Secretary General of CIHEAM, Mr. Cosimo Lacirignola, and the Manager of the Center for Mediterranean Integration (CMI), Mr. Mourad Ezzine, signed a Memorandum of Understanding (MoU) in order to undertake joint activities to contribute towards Development, Inclusive Growth and Youth Empowerment in the Mediterranean.

CIHEAM and the CMI encounter each other in Mediterranean research and cooperation, public policy and multilateral fora discussions, publications and activities able to increase debate in the Mediterranean countries and providing regional public goods.

CIHEAM and the CMI stress on the importance of improving the links between knowledge/capacity building and the needs of Mediterranean countries in a very strategic period for the regional development that requires more cooperation and more sustainability.

Therefore, the scope of the cooperation is mainly focused on the following issues: youth empowerment and employment, regional integration, inclusive growth, development of territories, environment and climate change.

CIHEAM and the CMI are firmly convinced about the need to reinforce the inter-institutional dialogue and set up synergic activities to face these important challenges for a safer future in the Mediterranean region.