Deliverable 5.10 Illustrated pilot case studies for the Black Sea Catchment Disaster Early Warning System

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Executive Summary

The illustrated pilot case studies for the Black Sea Catchment Disaster Early Warning System have been developed during 2009-2013 within the framework of the European Commission FP7 *enviroGRIDS* project (Building Capacity for a Black Sea Catchment Observation and Assessment System supporting Sustainable Development, Grant Agreement No. 26740).

Flooding and introduction of invasive alien species (IAS) are considered as global environmental issues, and are also important for the Black Sea area. Disastrous floods are one of the most serious environmental challenges for the Black Sea catchment area in the Danube and Elbe river basins, causing widespread devastation, economic damage and loss of human lives. The introduction of IAS in the Black Sea aquatic and terrestrial ecosystems, mediated by different human activities (pathways), threatens the natural biodiversity of the region and has already resulted in severe economical losses. Furthermore it also poses a serious risk for human health (for instance, release of human pathogens like *Vibrio cholerae* from within ballast waters of ships). Effective response to these disastrous events requires relevant management options, including development of operational early warning systems. In order to be effective, early warning systems must be people-centred and must integrate four elements - (i) knowledge of the risks faced; (ii) a technical monitoring and warning service; (iii) dissemination of meaningful warnings to those at risk; and (iv)public awareness and preparedness to act. The malfunctioning of one of these elements can result in a failure of the whole early warning system (UN, 2006).

Currently such operational early warning systems do not exist for the Black Sea region, and within the *enviroGRIDS* project we have conducted targeted research to address this issue and contribute to relevant capacity building. The purpose of this document is to present the results of our research activities as a series of targeted illustrated case studies, for their possible consideration in development of future operational early warning systems by relevant interested organizations on both EU and regional levels.

The present report consists of three parts: Part 1 contains case studies for Flood Risk Management (prepared by ANTEA); Part 2 encompasses case studies on Aquatic Invasive Species (prepared by SPSU in collaboration with associate partners of the project), and Part 3 consists of case studies on Terrestrial Invasive Plants (prepared by IGAR and DDNI). In these case studies, specific approaches for risk evaluation and management (including early warning) are provided. Also, the report includes practical recommendations for development of the operational regional early warning systems for both flooding (Part 1) and introductions of invasive alien species (Part 2).

Part 1 has achieved information gathering and development of case studies in order to know the state and make recommendations for further integrated flood risk management and development of the Disaster Early Warning System of the Black Sea Catchment. The Reni case study in Ukraine, for instance, has contributed flood risks assessments in locations with severe lack of data. The Koros case studies in Hungary attempts to: 1). assess the social impact of floods through the development of a GIS tool; 2). simulate a river system to design flood estimation; 3). analyse snow resources based on seasonal prediction.

Part 2 has demonstrated application of invasive alien species (IAS) related early warning indicators for several case studies: the Black Sea itself, and river basins of three main tributaries to the Black Sea - Danube, Dnieper and Don rivers. Specifically, our analysis of collected information on historical records of IAS indicated a substantial increase of rates of new species introductions during the last two decades in the Black Sea and its main tributaries. Targeted biological surveys of the upper Dnieper River and lower Don River revealed numerous locations with a high level of biological contamination. Also, the incorporation of Open Access journals in information systems on IAS is considered an innovative approach to IAS-related information management.

Part 3 included the risk assessment of terrestrial invasive plant species (ITPS) and the key driving forces responsible for their introduction and spread in some Romanian protected areas, namely some selected case studies for each biogeographical region in Romania: Rodna Mountains National Park and Maramureş Mountains Natural Park (Alpine region), Mureş Floodplain Natural Park (Pannonic region), Comana Natural Park (Contineтal region), Măcin Mountains National Park (Steppic region) and (Danube Delta Biosphere Reserve (Pontic region). For that purpose, in-depth cross-referencing of the biological and geographical scientific literature on the most relevant ITPS in the Romanian protected areas was carried out.

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Part 1: Case Studies for Flood Risk Management (Ethel Pirola Igoa, Annelies Beel, Trui Uyttendaele, Veronique Vandenberghe, Gabor Balint)

Abstract

Flooding is a global phenomenon which causes widespread devastation, economic damages and loss of human lives. Understanding flood hazard requires a better comprehension of the types and causes of flooding, their probabilities of occurrence, and their expression in terms of extent, duration, depth and velocity.

This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is to know where and how often flood events are likely to occur, what population and assets occupy the potentially affected areas, how vulnerable these people and their settlements are, and how these are planned and developed, and what they already do towards flood risk reduction. This is critical in grasping the necessity, urgency and priority for implementing flood risk management measures.

This part of deliverable presents some information and case studies to contribute to the Disaster Early System of the Black Sea Catchment with focus on flood hazard.

1.1. An integrated approach to flood risk management

An integrated flood risk management approach is a combination of flood risk management measures that taken as a whole, can successfully reduce flood risk.

Flood management measures are typically described as either structural or non-structural. Structural measures aim to reduce flood risk by controlling the flow of water, both outside and within urban settlements. They are complementary to non-structural measures that intend to keep people safe from flooding through better planning and management of urban development. A comprehensive integrated strategy should be linked to existing urban planning and management policy and practices.

Structural and non-structural measures do not preclude each other, and most successful strategies will combine both types. It is also important to recognize the level and characteristics of existing risk and likely future changes in risk to achieve the balance between the required long and short term investments in flood risk management. But as both urbanization and climate change accelerate, there may well be the need to move away from what is often today an overreliance on hard-engineered defenses towards more adaptable and incremental non-structural solutions (Jha et al., 2012).

Structural measures range from hard-engineered structures such as flood defenses and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers. They can be highly effective when used appropriately, as the well-documented successes of the Thames Barrier or the Dutch sea defenses. Structural measures can, however, be overtopped by events outside their design capacity. Many structural measures also transfer flood risk by reducing flood risk in one location only to increase it in another. The redirection of water flows also frequently has environmental impact. In some circumstances this is acceptable and appropriate, while in others it may not be. In all cases a residual flood risk remains. Structural solutions can also have a high upfront cost, can sometimes induce complacency by their presence, and can result in increased impacts if they fail or are overtopped, as was tragically illustrated in the tsunami in Japan in 2011.

The challenge with many non-structural measures lies in the need to engage the involvement and agreement of stakeholders and their institutions. This includes sometimes maintaining resources, awareness and preparedness over decades without a flood event, bearing in mind that the memory of disaster tends to weaken over time. This challenge is also made greater by the fact that most non-structural measures are designed to minimize but not prevent damage, and therefore most people would instinctively prefer a structural measure.

Integrated flood risk management also includes the recognition that flood risk can never be entirely eliminated and that resilience to flood risk can include enhancing the capacity of people and communities to adapt to and cope with flooding.

Generating the necessary attitudinal and behavioural change may take time and investment in wide communication and consultation. Flood management may hugely benefit by the involvement of stakeholders. Indeed, if the communication and consultation challenge is successfully overcome, the gains in flood resilience are significant.

It is also important to take account of temporal and spatial issues when determining strategy. Integrated urban flood risk management takes place at a range of scales, including at the river basin and water catchment as a whole. This is due to the fact that the source of flooding may be at some distance from the city or town. Often the best option may be to tackle flooding before it reaches the urban setting.

Nonetheless, the specific solution, or set of solutions, which is optimal in a particular location can only be acheived after extensive evaluation, cost benefit analysis and consultation with multiple stakeholders. The measures selected will need to be negotiated with the relevant stakeholders, and will need to be adaptable to natural, social and economic conditions which can be expected to change over time.

1.1.1. Measures for flood risk management

1.1.1.1. Structural measures

Structural measures are used to control the flow of water both outside and within urban settlements, within the context of an integrated approach to urban flood risk management. These measures are traditionally viewed as structural hard-engineered solutions, such as drainage channels, as well as more natural and sustainable complementary or alternative measures, such as wetlands and natural buffers.

Some of these measures are:

- **Conveyance**: In the context of flood risk management, the purpose of conveyance is to provide a route to take potential flood water away from areas at risk. Traditionally this has been seen as a way to remove the problem of flooding from the urban environment. Such systems often form part of a much broader water management approach including, for example, hydro-electric schemes in which control of excess flows forms a part. Some of the means of conveyance include modification of rivers, design of relief channels, floodplain restoration and reopening of culverts.
- **Flood storage**: storage has the effect of attenuating floods (reducing peak discharge).. This is especially true when there is a significant volume of storage available and the outflow is controlled. There is a water storage capacity in all parts of the natural water cycle that can be enhanced by creating additional opportunities for storage within a catchment. Storage occurs naturally in a catchment, for example within the floodplain or, more locally, in ponds. Artificially created storage facilities include flood storage reservoirs, retention ponds and detention ponds; deliberate flooding of farmland, or urban areas like playing fields or car parks, may also be utilized. Some major reservoirs on river systems, while providing attenuation that is relevant to flood risk, may have additional functions such as water supply or hydroelectric power generation.
- **Drainage systems**: Urban drainage systems need to be able to deal with both wastewater and stormwater whilst minimizing problems to human life and the environment, including flooding. Urbanization has a significant effect on the impact of drainage flows on the environment: for example, where rain falls on impermeable artificial surfaces and is drained by a system of pipes, it passes much more rapidly to the receiving water body than it would have done when the catchment was in a natural state. Issues to take into consideration when talking about drainage systems are: combined or separate sewer systems, drainage system versus overflowed drainage system, interface with river systems, semi-natural systems and surface water management plans.
- **Infiltration and permeability**: urbanization affects the natural water cycle. When rain falls, some water returns to the atmosphere (through evaporation or transpiration by plants); some infiltrates the surface and becomes groundwater; and some runs off the surface. Since urbanization increases the proportion of the surface that is impermeable, it results in more surface runoff and reduced infiltration. Surface runoff finds its way to a watercourse far quicker than groundwater and therefore increases flood risk, and if the surface runoff is conveyed via a piped drainage system the effect is even more pronounced. Therefore, it is important to include initiatives such as infiltration devices, vegetated surfaces or permeable paving into urban flood management plans.
- **Groundwater management**: In unsaturated ground, rain infiltrates into the ground and percolates downwards until it reaches the water table, below which the pores and cavities of the ground are saturated with water. Here the water moves laterally, generally slowly, under the influence of the gradient of the water table and the form of any underlying impermeable stratum. The water-bearing strata, or 'aquifers,' may consist of unconsolidated materials like sands and gravels, or consolidated materials like sandstone and limestone. Groundwater discharge provides the base flow in rivers and continues during long periods without rainfall. Where the water table, or the surface of the aquifer, intersects the ground surface, groundwater is released via springs. During floods there can be rapid changes in groundwater outflow especially from confined aquifers. Groundwater management is important due to the influence it can have in flooding, land subsidence and rainwater harvesting.

- **Wetlands and environmental buffers**: Measures for reducing the amount and speed of rainwater runoff can include utilizing wetlands, both natural and man-made, and increasing the amount of green vegetation. From the flood management point of view the key purpose of wetlands and environmental buffers is to act as flood retention basins and hence reduce the flood risk. In urban areas, these 'greening' measures can be at a micro level, such as gardens and grass verges of streets. On a wider scale, there is the provision or designation of managed green areas within the urban space, such as an interconnected network of designated wetland areas, linked to existing natural wetlands through a program of tree and hedge planting.
- **Building design, resilience and resistance**: Where buildings are situated in the floodplain, even if they are protected to some extent by structural flood defenses, there will still remain some residual risk of flooding. Careful design of buildings can reduce the vulnerability of buildings to flood damage and can therefore reduce the residual risk and enable occupation of floodplain areas. This can be particularly important for existing settlements which cannot be relocated, or where the advantages of floodplain occupation outweigh the cost of building design. There can be three approaches: Flood resilience (wet proofing) helps to reduce the damage when floodwater enters the building, particularly structural damage, but it does not prevent floodwater entering. Flood resistance (dry proofing) seeks to prevent water from entering the building, to reduce damage to the building, the fixtures and fittings, possessions and reduce the effect on occupants. Flood avoidance aims at avoiding the floodwater entirely, by locating buildings above the flood level, elevating or raising buildings above the flood level, or to allow buildings to rise with the floodwater.
- **Flood defenses**: The threat of flooding has been present since people began to settle close to rivers and coasts in order to maintain trade and communication links. For centuries, therefore, it has been necessary to protect these areas from flooding, by building defenses that supplement natural features such as river banks. Flood defenses are intended to reduce the risk to people and the developed and natural environment from flooding. Some examples are inland flood defenses (walls, embankments), coastal flood defenses (levees, breakwaters), flood barriers, demontable and temporary flood defenses, or property level defenses.

1.1.1.2. Non - structural measures

Non-structural measures are used to manage the risk of flooding for cities and towns and their inhabitants. These measures do not require extensive investment in hard-engineered infrastructures, as typically do structural measures, but rely instead on a good understanding of flood hazard and adequate forecasting systems. There are four main categories, as follows:

- Increased preparedness
- Flood avoidance
- Emergency planning and management
- Speeding up recovery and using recovery to increase resilience.

Many of the measures, such as early warning systems, will form part of any flood risk management scheme. They can be seen as a first step in protecting people in the absence of more expensive structural measures, but they will also be needed to manage residual risk where such schemes have been constructed.

Some of these measures are:

- **Flood awareness campaigns**: Flood risk awareness is the cornerstone of non-structural flood risk management. All actions to minimize the impact of flooding hinge upon stakeholders becoming aware these are both necessary and desirable. Ignorance of flood risk encourages occupation of the floodplain, in the first instance, and can allow appropriate building design practices to fall into disuse. In the event of a flood, the lack of awareness of risk can result in a failure to heed warnings to evacuate, thereby endangering lives. Raising awareness should be accompanied by information on measures and steps which will mitigate the flood risk. The range of interest groups involved includes governments (at different levels), local agencies, businesses and individuals. Many people will fall into more than one of these groups, so the messages need to be consistent across interest groups and yet be targeted to the knowledge requirements of each group. This is why, when designing a flood awareness campaign, different communication channels should be used, and awareness should be monitored. The use of visual clues in the landscape, such as flood markers also helps people keep flood risk in mind.

- **Health planning and awareness campaigns**: An urban flood event requires immediate measures to ensure that citizens have safe drinking water, including appropriate excreta disposal, disease vector control and waste management, as floods can make it difficult to maintain dignity and hygiene, and lead to an increase in the risk of disease. Health Awareness Campaigns are vital 'soft' interventions alongside hardware provision (waste water treatment, for example); together they can help preserve public health by increasing preparedness. Several target groups are fundamental: municipal staff, volunteers and health professionals; the general public and in particular vulnerable groups, and media workers.

- **Land use planning and flood zoning**: Ongoing development and encroachment of floodplains and other flood-prone areas is a consistent problem throughout the urbanized world. The need to integrate flood risk management into land use planning is vital in order to minimize the rise in exposure to hazard, and to seek to manage the consequences of flooding. The interaction between land use planning and flood risk management is mutual. Urban land use plans should ideally be integrated within a suite of flood management plans which may include river basin management plans, coastal management plans and surface water management plans. Such plans are likely to be the responsibility of different governmental departments or agencies. Land use plans need to incorporate flood risk alongside other priorities, such as land availability and environmental hazards while broader spatial plans will need to balance the need for urban growth with the desire to limit flood risk.

- **Flood insurance, risk financing, compensation and tax relief**: these measures have two main purposes in the management of flood risk. Firstly, and most obviously, the provision of these financial mechanisms can be used by those at risk to offset their financial risk from flooding. Although these financial tools obviously do not prevent flooding, they allow recovery without placing undue financial burdens on those impacted by flood disasters. The second major function of disaster insurance, compensation and tax relief schemes is to reduce risk and damage, via the need for risk assessment and encouragement of risk mitigation. If risk is correctly priced then the incentive to mitigate risks exists via premium pricing; many insurance contracts also implicitly require the policyholder to undertake reasonable risk reduction and mitigation activities and this obligation can be made more explicit, or mandatory, for coverage to apply. Similarly, compensation can be targeted to resilient reconstruction, whilst tax schemes have the potential to influence many aspects of reconstruction, including the use or set aside of flood-prone land.

- **Solid and liquid waste management**: The inadequate collection and disposal of waste is often a significant contributor to flooding. The principal concern in being prepared for flood events in urban environments is the blockage of drainage, and also the infilling of storage areas and ponds which may provide temporary storage for flood waters. Uncollected solid waste blocks drains, and causes flooding and subsequent spread of waterborne diseases. Waste management plans should consider collection, disposal and treatment of the different types of wastes, and the maintenance of the whole system.

- **Emergency planning**: It is vital to recognize that even after the implementation of structural and non-structural flood mitigation measures, residual flood risk will remain. It is of paramount importance to make plans to deal with flood events and their aftermath. This involves multiple activities which can be included as part of a flood emergency plan. Identifying existing internal and external organisations such as government organisations, the private sector and the civil society, damage avoidance, flood emergency preparedness activities and evacuation and rescue activities are crucial issues in emergency planning.

- **Business and government continuity planning**: After a flood disaster, some organizations, mechanisms and sectors may be able to continue to deliver their most critical services. Others may find it much more difficult to perform effectively under the adverse consequences of a flood disaster. It is important to assess the ability of individuals, government and non-government organizations, mechanisms and sectors to continue to perform critical functions under different flood scenarios.

Depending on the result of this assessment, priority should be given to repair public infrastructure or maintain services that would experience a higher degree of operational problems in an emergency.

- **Forecast and early warning systems**: The purpose of early warning systems (EWS) is to give advance notice of an impending flood, allowing emergency plans to be put into action. EWS, when used appropriately, can save lives and reduce other adverse impacts.

  The four main essentials for any flood warning system are:

  - Detection of the conditions likely to lead to potential flooding, such as intense rainfall, prolonged rainfall, storms or snowmelt
  - Forecasting how those conditions will translate into flood hazards using modelling systems, pre-prepared scenarios or historical comparisons
  - Warning via messages should be both, locality- and recipient relevant, and broadcasting these warnings as appropriate
  - Response to the actions of those who receive the warnings based on specific instructions or pre-prepared emergency plans

- **Flood recovery and reconstruction**: Not all floods can be defended against: the planned recovery from a flood event is a valuable tool in flood risk management, and forms a part of a flood resilient mentality. As discussed above, emergency warning and evacuation together with the construction of the most resilient critical infrastructure and buildings is a planned way of ensuring in advance that the need for recovery and reconstruction is minimized. However, there will inevitably be some damage necessitating reconstruction. As full reconstruction can take many years, it is important to do two things: firstly, to ensure that normal life can be resumed despite the on-going reconstruction work; and secondly, to shorten the time taken for reconstruction as much as possible. Gaining access to flooded areas is the first stage. Next, a rapid assessment of the state of critical infrastructure will help to establish the extent and scale of damage and inform plans for getting the critical infrastructure up and running again at a national level. Coordination of recovery efforts throughout all sectors can then be most easily achieved.

1.2. Flood forecasting and early warning systems

Flood forecasting is the use of real-time precipitation and streamflow data in rainfall-runoff and streamflow routing models to forecast flow rates and water levels for periods ranging from a few hours to days ahead, depending on the size of the watershed or river basin. Flood forecasting can also make use of forecasts of precipitation in an attempt to extend the lead-time available.

Sophisticated flood forecasting systems will also account for the effects of snowmelt, flood plains and wash lands, flood defenses, tidal effects near the sea, and sea-surges.

Flood forecasting is an important component of flood warning, where the distinction between the two is that the outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations, while "flood warning" is the task of making use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted.

The key issue involving flood and calamity management is the availability and operationality of technical decision support tools. Real-time flood forecasts are an essential tool for the management of flood events. The primary input for decision makers involves real-time advice taking account of:

a) trustworthy identification of potential flood events in the near future

b) detailed forecasts of flood magnitude, extends and timing for previously identified high risk events

c) reliable warning system.

This operational output contributes to increased preparedness in an upcoming flood event: preventive/emergency measures can be taken, evacuation plans can be activated and even rescue operations and victim support can be arranged in advance.

Currently existing flood forecasting and warning systems have shown to be useful at a wide range of levels: policy makers and administrative authorities, civil services, industry and local inhabitants.

1.2.1. Operational Flood Forecast and Warning System (OFFWS)

Although the term "Operational Flood Forecast and Warning System (OFFWS)" is quite explicative by itself, it encompasses several characteristics and functionalities that require some further explanation:

Operational

It is a system working in real-time. This means that operators can monitor and evaluate the situation on-line taking in account the most recent developments in weather (forecast) conditions and operational features of water control structures. The system can show what is actually happening at this very moment by gathering gauged data at hydrometeorological stations, external weather forecasts, radar images, remote sense data, etc.

Flood forecast

The information of the present condition, gathered in real-time, combined with weather forecast information forms the basic input for a set of numerical models which compute the flood forecasts. Several numerical models are consecutively used at this stage (as a numerical model chain) including: digital terrain models, rainfall-runoff, hydrodynamics for relevant river reaches and flooding.

Given the fact that weather forecasting involves uncertainties of different nature and magnitude, ensemble prediction forecast can be used at this stage to estimate a possible range of outcomes.

Warning

The system works continuously in an autonomous way. It has the ability to detect critical conditions in the near future by analysing the data of the present condition together with the computed forecasts from different data sources at regular intervals. As soon as an imminent critical condition is identified, a warning protocol is triggered and alerts key institutions. This protocol can be defined in such a way that:

a) operators are warned automatically by email, sms or fax

b) summary reports of the (flooded) situation are produced including tables, charts and maps in different formats. These reports are automatically sent to authorities, civil services, industry and even civil population

c) information contained in websites can be automatically updated according to the latest developments.

All the forecasts are performed for a "present condition", a condition replicating the current situation, infrastructure and operational policy. Likewise, the system allows the operator to analyse hypothetic scenarios in parallel, so that the effect of "what if..." modifications can be evaluated. This tool permits studying in real-time what would happen if e.g. the operation of a gate was modified before actually doing it on terrain. Impact of changing current operational policies can be evaluated in advance.

The working of an operational flood forecast and warning system can be envisaged as a decision support tool; comprising a set of modules or components that are closely interrelated:

Data gathering module

This module takes care of collecting real-time hydrological data from different sources as telemetric stations, weather radars and satellites, hydroclimatological forecasts, etc. This module is the watchful eye of the system that continuously gets input of the present hydroclimatological conditions and future estimations provided by weather forecasts institutions. The operators can visualize the present weather conditions as expected forecasts through the Graphical User Interface or GUI.

Forecast module

This module makes predictions of future water flow and/or flood conditions based on a chain of numerical models that transform rainfall data into runoff, water flow and flood events in time. These software tools constitute the computing heart of the system; the computing engines are usually running in high performing and reliable hardware systems.

Warning module

This module is responsible for warning and alarming the operators and general public when the operational system shows any kind of functional abnormality or when critical conditions are expected. The system analyses continuously the incoming data, logs and numerical results from the computing engines, triggering an alarm under certain previously configured conditions. The alarm protocols can rely on different technologies to warn the real world: email, fax, sms, web.

Decision Support module (DS)

A DS module allows operators to try out alternative management strategies in real-time. Decision makers can try out e.g. the impact of opening a breach on the dike before calling the field operator or contractor for carrying it out. The result of altering the control policies of a series of gates can be analysed in advance. This module allows water managers to search for a tailored solution for every critical situation throughout an infinite range of tryouts with real data.

Ensemble Prediction Systems (EPS)

This module provides the use of probabilistic methods that take into account the chaotic behaviour of the atmospheric synoptic flow in weather forecasts. The module allows extending the probabilistic approach to the flood forecasting.

1.3. The state of the Early Warning System in the Danube Catchment

The first international flood forecasting system in the Danube region, providing an early flood warning, was launched in March 2008 by the International Commission for the Protection of the Danube River (ICPDR, 2008) and the Joint Research Centre (JRC) of the European Commission.

The system provides flood forecasts for large floods to national authorities within the Danube River Basin with a time lag of up to 10 days. Examples of national response measures include opening temporary flood retention areas, building temporary flood protection structures (like sandbag walls), implementing civil protection measures (such as closing down water supply systems to avoid contamination) and evacuating community residents.

Following the disastrous 2002 floods in the Danube and Elbe river basins, the ICPDR accepted the JRC's offer to develop and test a basin-wide flood alert system. `Danube-EFAS´ is now part of the JRC´s European Flood Alert System (EFAS), used by 25 national authorities across Europe and covering over 85 per cent of the continent's major international river basins. Austria, Bulgaria, Czech Republic, Germany, Hungary, Moldova, Serbia, Slovakia, Slovenia, and Romania signed the initiative to develop the Danube-EFAS.

EFAS complements - but does not replace – the existing national flood forecasting systems and improves flood forecast through user feedback. Danube-EFAS information is available through a password-protected website, 24 hours a day, through an online service managed by the JRC. The system currently includes 700 rainfall stations in the Danube Basin, which are planned to be increased to around 3,000 stations through an ongoing European-funded EU-FLOOD-GIS project carried out by JRC. Information includes rainfall and flood forecasts throughout the river basin, and maps showing rivers potentially reaching critical alert levels for all Danube tributary rivers with upstream areas larger than 4,000 km2.

Yet, many areas do not have enough data or tools to manage flood risk. In the following paragraphs some pilot studies are presented, showing initiatives to asses flood risk even in data scarce areas.

1.3.1. The Reni Case Study, Ukraine

(by Vandenberghe V., Bart P.J., Dyakov O., Huygens M., Kornilov M., Rocabado I., Sizo R. & Studennikov I.)

1.3.1.1. Assessing flood risks with severe lack of data

The aims of the project were 1) to share expertise on flood risk mapping, emergency management and damage calculation 2) to create better flood prevention and protection plans for the Ukrainian part of the Danube Delta 3) to contribute to the set up of an integrated flood risk management plan in line with the Water Framework Directive (WFD) and EU Flood Risk Directive 4) to assist with capacity building and community involvement in order to enhance flood risk management and 5) to formulate recommendations for data collection.

Introduction

The city of Reni is under threat of flooding from the Danube river as well as from flash flooding due to extreme rainfall from a smaller river which runs through Reni. The area of Reni was chosen as a case study for several reasons. It is a community where during a flood not only 8000 population and housing are at risk but also a harbor and a water intake for water supply. The local community and the water managers, together with the Danube Flood Protection Department, the Emergency services, the Town of Reni and the Centre for regional studies in Odessa were all giving their full support to this project.

Normally state of the art models are used to execute a flood risk assessment. These require however al lot of (detailed) data. In the Reni case there was a severe lack of detailed data. By involving the right stakeholders and by using their local knowledge, useful results can be produced and can be the start for a more effective flood risk management. In this way a flood risk strategy can be formed without having all the data beforehand.

In earlier days only structural mitigation measures (like dams, dikes, …) were implemented to limit flood damage. Nowadays, flood risk management comprises a lot more and is developed alongside the risk management cycle: before, during and after the flood (Figure 1.1). It is of crucuial importance to make the right decisions during all these steps during flood risk assessment.

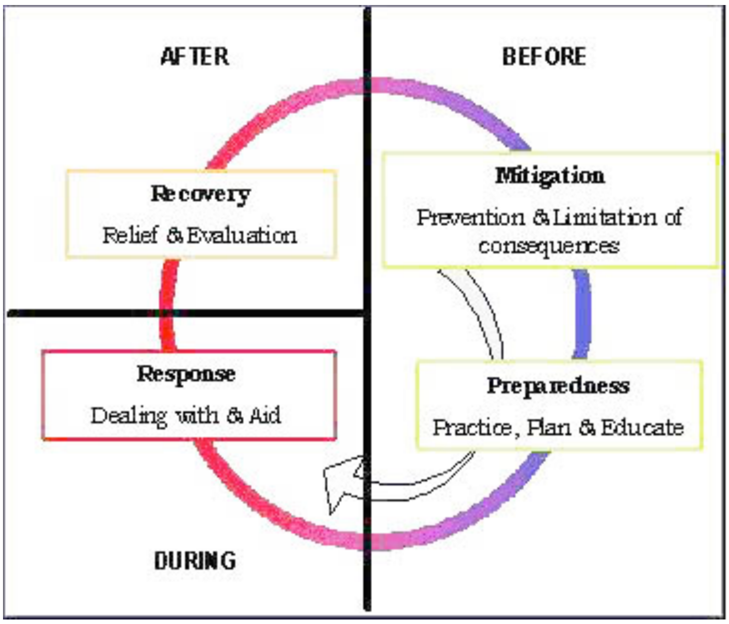

Figure 1.1. The different steps in flood risk management.

Reni case study

Reni is a small town in the Odessa Oblast of Western Ukraine (Figure 1.2). The risk of flooding comes from two sources: flood damage caused by high water levels in the Danube River (associated with risk of dike breaches) and the appearance of flash floods due to heavy rainfall and runoff from the upstream Balaneshty hilly catchment. The combination of two potential flood sources leads to a severe level of flood risk (higher flood probability and higher impact). Furthermore extra management issues are to be taken into account by developing a proper flood risk management along this international Ukrainian-Romanian Danube delta stretch.

The red and yellow lines in Figure 1.2 show the flood extent of a major flood event that took place in 2005 and that was induced by two different sources: a flashflood (red) and river flood (yellow).

For the moment there is not a comprehensive flood risk management plan available. When a flash flood occurs, or when a river bank along the Danube River seems to collapse, the Department of Emergency Planning helps where they can by reinforcing dikes with sand, and by helping and rescuing people who are trapped by the flash flood. Actually, in the flood safety chain only some very limited actions are taken before the flood event take place and most of the flood risk management is situated in the response phase (after the flood event). The severe flood of 2005 completely destroyed a large number of houses and part of the infrastructure while a lot of Reni inhabitants were trapped in the flooded city.

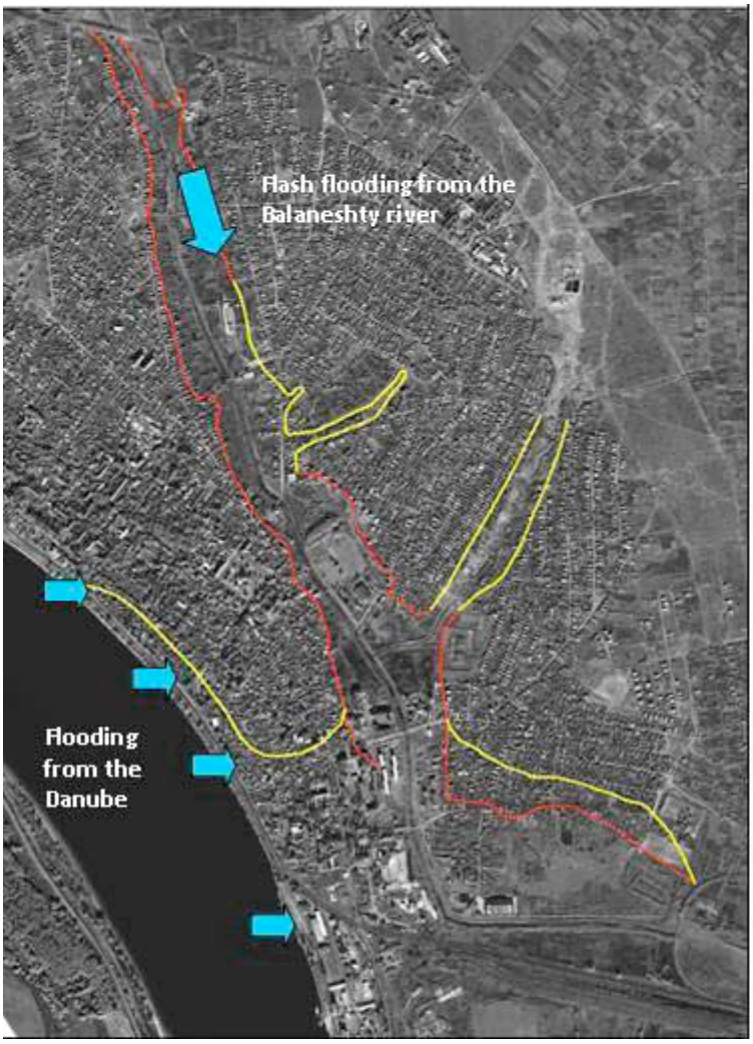

Figure 1.2. Threats to flooding and delineation of the 2005 flood extent.

Methodology

Flood extents (in space and time) and associated flood depths are deduced and visualized on a map for a real event that occurred in the past and or different hypothetical storms (with different return time periods).

To determine the flood extent and flood depth the flash floods are numerically modelled. For this case study, this hydrological-hydrodynamic schematization of the river environment was done with the use of InfoWorks RS software. InfoWorks RS includes full solution modelling of open channels, floodplains, embankments and hydraulic structures. Rainfall-runoff simulation is available using both, event based methods and conceptual hydrological methods. Full interactive views of data are available using geographical plan views, sectional view, long sections, spreadsheet and time varying graphical data. The underlying data can be accessed from any graphical or geographical view.

Nothwithstanding the fact that lack of data impede the creation of flood maps, it will be shown that this hurdle can be overcome and that useful maps can be produced.

The modelling approach towards the computation of flood maps relies on the set up of different numerical models interacting together (Huygens et al., 2009). The models are calibrated with available historical data. The following models were set up: Digital Terrain Model (DTM), Rainfall-Runoff (RR), Hydrodynamic model (HM) and Flood mapping model (FMM).

The key issue in flood mapping is the representation of flooded areas related to a certain statistically determined return time period. The procedure above ends up providing a tool that transforms rainfall data into flooded areas. A final step comprises the statistical analysis of several flood events in order to derive the frequency of occurrence. Therefore an Extreme Value Analysis on the results at each model node for multiple simulations is carried out. For this purpose a synthetic set of rainfall events was generated to mimic the available characterization of rainfall parameters. Each of these events was simulated with the hydrodynamic model ending up in a cloud of stage and discharge values on each one of the 125 cross sections. At each location an Extreme Value Function was fitted for stages; subsequently the fitted function was used to generate stages for several return time periods. Stages for corresponding return time periods lead finally to the required flood maps through the flood mapping modelling.

Data availability

Data for analysis was mainly provided by local authorities and stakeholders within the region. As a general characteristic it was scarce while resolution and reliability were limited. The following data was available:

- Topographic surveys: A limited number of cross sections were surveyed and documented in the report about the 2005 flash flood. This data, originally in analogue format, was digitized for subsequent use.
- Structures: The locations of 11 bridges along the Balaneshty River reach where known information on the flow openings under the bridges was limited; surveyed dimensions were not available. There is no evidence of water control systems (gates or weirs) with manual or automatic control.
- Satellite imagery: Satellite imagery becomes important when available surveyed data is not sufficient to describe topographical features of the terrain with sufficient accuracy. For Reni 3 different sources were used:
    - ASTER Global Digital Elevation Model; (ASTER GDEM), a DEM data which is acquired by a satellite-borne sensor "ASTER" to cover all the land on earth with horizontal resolution of up to 30 m.(http://www.gdem.aster.ersdac.or.jp/)
    - SRTM digital elevation data, produced by NASA. Through the CGIAR-CSI GeoPortal SRTM 90m Digital Elevation Data for the entire world is available. (http://srtm.csi.cgiar.org/)
    - Reni Satellite image with 5 m horizontal resolution.

- Climatological data: Climatological data for Reni was limited to short time series of rainfall and evaporation for July 2005, gauged at stations Reni and Nagornoe. For the stations Bolgrad, Izmail and Vilkobo, located outside the study catchment, a long time characterization of rainfall parameters limited to monthly parameters (maxima, minima and averages) for a gauging period between 1945 and 2005 was also available. Water levels gauged at the Danube in Reni and at the Kagul Lake were also reviewed. Flow discharge data was not available.
- Historical floods: This is a key input in order to calibrate the numerical models allowing them to produce realistic outcomes. An analogue plan containing a delineation of zones that were flooded in July 2005 was the only historical information that could be used. Personal observations by some privileged stakeholders have helped us to reconstruct the flood picture of the 2005 event, both in a qualitative and quantitative way.
- Site visit and photo report: During a site visit to Reni the Balaneshty river was photographed. At the hand of this photo-report a general idea of the conveyance capacity of both the river cross section and the bridges could be derived based on expert judgement.

Results

On the basis of the model and the available data a lot of flood risk maps of the region were created. These flood risk maps were used to enhance both technical training and operational capacity building. Furthermore an infomarket was organized where stakeholders were brought together. During a first session, specialists in flood management (modellers, emergency planners, water managers and policy) were invited to discuss the results of the model for Reni and how a better flood risk management plan could be set up with the aid of the newly created information and maps. A second session of the infomarket was held publicaly and people could learn from the results (mainly maps) of the project. This way, the inhabitants could assess the flood risk of their house and identify an evacuation spot. Different experts were present to help the people with there questions and to hear their ideas. The main idea behind the infomarket was:

- to focus on methodology rather than on technical details, making the steps in flood risk mapping easier to follow for lay people
- to provide results to the stakeholders, allowing them to actively take part in the discussion and show the benefits of flood risk mapping
- to actively involve the public and raise awaireness on flood risk and the importance of data availability. Data gaps were identified and it was shown how the obtention of data in a relatively early stage is needed for flood risk mapping and what effort is required to acquire that necessary data. Gathering data enables the selection of effective flood risk management measures.

In Figure 1.3 the obtained flood risk maps are presented with different return time periods. Figure 1.4 is a flood risk map for the 2005 flash flood event, together with indication of critical points, bridges, evacuation routes, gathering spots. Together with this map a house is shown with indication of the flood depth as indicated with colours on the maps. That makes it very visible and understandable for the public what will happen.

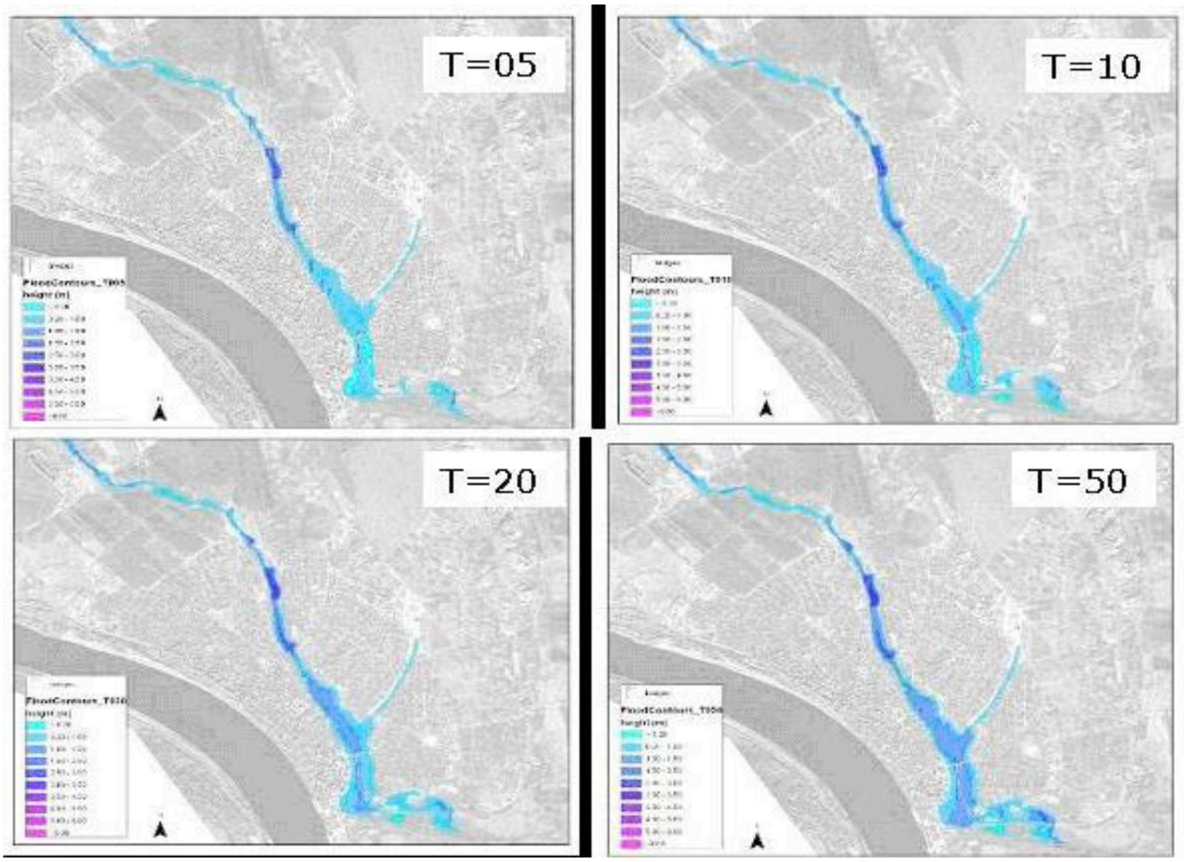

Figure 1.3. Flood risk maps with different return periods: 5, 10, 20 and 50 years.

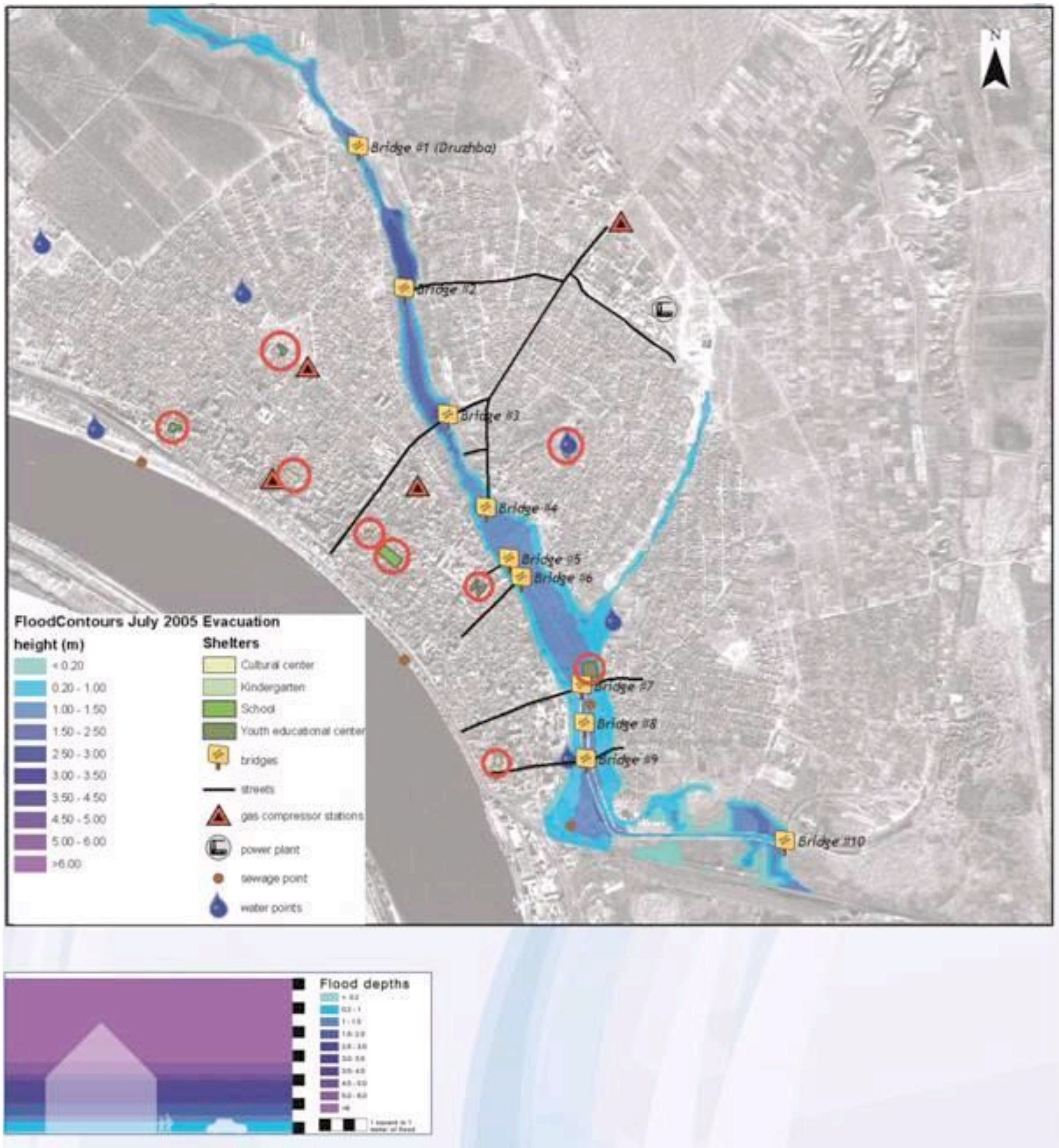

Figure 1.4. Flood risk map of the July 2005 flash flood event with indication of evacuation shelters, bridges, water points, …

By showing important points on the maps, people can see very clear what will happen during a flood. That might be a bridge that one will not be able to use anymore or they can see that a possible shelter place, like a cultural centre will be flooded with less than 20 cm. For emergency planners these maps will also reveal a lot of extra information to set up an emergency plan. It will for example show if drink water inlets will be flooded or what kind of evacuation routes must be communicated to the people living in flood prone areas, etc..

Recommendations for data to create more accurate maps and plans:

Topographic surveys: The geometry of the conveying channels is currently not sufficiently accurate; the broad irregular bedding may need to be topographically surveyed at intervals of at least 200 m. and extending at least 20 m beyond the actual embankments. The extent of frequently flooded zones is well known; surveys within these zones should be sufficient to delineate the flooding patterns.

Structures: All the structures, such as bridges and culverts, need to be surveyed more systematically and more detailed. Important at this point is a clear idea of the conveying areas (width, depth, high, etc). For structures, which may be overtopped (culverts, dikes, embankments, etc), flooding thresholds become important. When relevant for urban drainage/sewer systems discharging into the main channel, locations and weir dimensions will be necessary.

Climatological data: Rainfall, evaporation, water levels and river discharges are required parameters for the numerical hydrological and hydrodynamic model development. This is currently a major gap in the simplified approach. For each one of these parameters there are two types of datasets that need to be obtained: long time series and historic events. Long time series within the catchment can not be produced any more the alternative is obtaining this sets for neighbouring locations or locations displaying similar characteristics but further away from the study area. A proper data registration for events in the future can be gauged relying on the implementation of a new gauging network comprising at least a couple of stations where water levels and water flow are recorded in a systematic and continuous way. In recent years, some climatological data, obtained by satellite imagery, has become available for certain parameters like rainfall, temperature and evaporation. The most important advantage of this source (radar spots) is the spatial coverage and variability of the data; less attractive is the time resolution (3 to 9 hours sometimes) which can be a disadvantage for small catchments. For this kind of global spatial data ground thruthing with local observations is strictly needed to have a more reliable calibrated dataset.

Historical floods: Historical characterisation is a practical alternative when gauged data is insufficient. Based on bibliographic research and interviews with local authorities and stakeholders it is possible to qualitatively reconstruct important flood events in the past. Depending on the sources, even a limited quantitative character can be achieved. The characterisation can be time consuming but it usually delivers very enriching input for both modelling and management.

Economic data: A database with economic data about value of properties, landuse, railways, roads, harbour, and water intake point should be available to calculate possible economic damage.

Conclusions and recommendations

This project showed how already flood risk maps can be created and be useful even without a lot of data or detailed data. This project could start a lot of activities like expertise building around flood risk mapping, set-up of emergency plans and public awareness raising. All this was done on case study level in the city of Reni. Now the results should be used to start these activities in the whole Ukrainian part of the Danube Delta. Also in Reni still a continuation of the started activities is needed. Not the least the collection of more data and the upgrade of their existing data. Upgrading data sources implies the need of upgrading, enhancing and recalibrating all the numerical models. Based on new surveyed data it will certainly be possible to produce a new DTM fitting better the actual topography of the main channel and flood plains. With adequate climatological data it will be feasible to develop a set of conceptual RR models. PDM seems a good alternative to investigate. New survey data and RR models will lead to a new conceptualisation of the hydraulic and flood mapping models. The all around result would be a more accurate and reliable set of flood maps which provide a better understanding of the risk and allows for effective measures (both in effectiveness and cost efficiency).operational flood forecasting and warning system.

1.3.2. The Koros Case Studies, Hungary

1) Assessing the social impact of floods - development of a GIS tool.

(by Annelies Beel, Trui Uyttendaele, Robbe Naudts, Stefaan Van Hoed)

ABSTRACT This study aims to assess the vulnerability of a community located in a flood prone area. A GIS tool called SoFLIM is developed (ArcGis 10.0, Model Builder) in order to assess graphically differences in social impacts of floods.

The assessment is based on a social flood impact analysis that combines susceptibility, adaptive capacity, flood characteristics and the exposure level of the people towards flooding.

The tool is applied to the village of Szelevény, located near the Körös river in Hungary. As expected, the flood index is the most important parameter when evaluating flood vulnerability. Since the central and Southern part of the village is most frequently flooded, the highest social flood impact occurs in these areas. Differences between the former mentioned areas are observed due to a higher susceptibility to floods in the Southern part in comparison to the central part of the village.

Keywords: Szelevény, social flood impact, indicators, GIS tool

2) Braided river system simulation based results of design flood estimation for the Koros Tisza confluence.

(by Gabor Balint, Peter Bakonyi, Andras Csik, Gabor Liptak, Beata Zsidekova, Jozsef Szilagyi)

ABSTRACT A hybrid, seasonal, Markov chain-based model combined with Discrete Linear Cascade Model flood routing is used for daily streamflow generation in the braided river system of the Tisza. The simulation technique applied uses stochastically generated diurnal increments of the rising limb of the main channel hydrograph combined with fitted, seasonally varying distributions in combination of an additional noise term whose standard deviation depended linearly on the actual value of the generated increment at the principal upstream station. Increments of the ascension hydrograph values at the tributary sites were related by second-order polynomials to the main channel ones together with an additional noise term whose standard deviation depended nonlinearly on the main channel's actual increment value. The recession flow rates of the tributaries as well as of the main channel were allowed to decay deterministically in a nonlinear way. Three thousand year of simulation was performed for the selected river network using the simplified hydrodynamic module. The Koros-Tisza confluence is represented by the Tisza – Csongrad station where extreme flood hydrographs were analyzed. It is expected that simulation results revealed extreme coincidences not observed directly but resulting from the observed type of flood generation patterns.

Keywords: streamflow generation models, Markov chains, hydrograph, DLCM model

3) Analyses of snow resources based seasonal prediction of Danube and Tisza spring flow and flood peaks.

(by Balazs Gauzeri, Zsolt Mattanyii, Beata Zsidekova, Gabor Balint)

ABSTRACT Precipitation falling to the land surface is one of the most important elements of the hydrological cycle, and it is the only input term of the water balance on the earth surface. In those areas of the Earth where a part of the annual precipitation falls in form of snow the rhythm of the hydrological cycle, that is that of the water balance within the year, follows a pattern that deviates from that of the precipitation record. Precipitation falling in solid state enters the hydrological cycle with a time lag that might be as much as several months after the precipitation event. Therefore, instead of considering the observed values of precipitation when describing various elements of the hydrological cycle, it is more expedient to take the surface water input into account. This is the fraction of precipitation which is present in the land surface in liquid state. Consequently the most important task of the various snow models within rainfall –runoff and water budget schemes is to transform the observed precipitation values into surface water input values. Spring time runoff largely depends on the snowmelt component and it gives a possibility to estimate expected seasonal volume of flow and flood peaks. Seasonal forecasts based on the relationship between snow resources and expected precipitation during spring months have been analysed for the Danube and Tisza rivers.

1.3.2.1. Assessing the social impact of floods - development of a GIS tool

Introduction

Due to climate changes and human activities a lot of places in the world are dealing with increasing natural hazards such as floods. Floods are caused by a variety of factors, both natural and man-made.

One of the major man-made causes of floods is deforestation or tree logging in vast areas. As a consequence, soils are more exposed to erosion processes and increased solid transport and sedimentation occur in river beds and seas. This diminished water storage capacity besides the rising water discharges lead to flooding.

The common practice of humans to build homes and towns near rivers and other water bodies (e.g. within natural floodplains) has contributed to disastrous consequences. Large paved superficies increase runoff, hinder infiltration and induce faster and higher floods downstream.

Another mayor human stressor is the transformation of landscapes with meandering rivers to straightened channels which decrease water storage capacity.

The Tisza River in Eastern Europe is one of those regions in the world where communities are at significant risk of flooding. The upstream part of the river (outside of Hungary) suffers from flash flooding while the middle section and downstream part of the river demonstrates extreme peak discharges and long lasting flooding (Floodsite, 2012). These hazards became exacerbated due to drainage measures undertaken in the 18th and 19th centuries. These measures resulted in a shortened river course (40% of original length) and consequent increased velocities, riverbed erosion and decreased floodplain area from 7542 km² to 1215 km² (Tóth & Kovács, 2007). The area of interest in this study is the Middle Tisza and more specifically, the settlement of Szelevény in the Jász-Nagykun-Szolnok County in Hungary (Szelevény, 2012). The evolution of the flood situation in the nearby city Szolnok is documented and is illustrated in Figure 1.5.

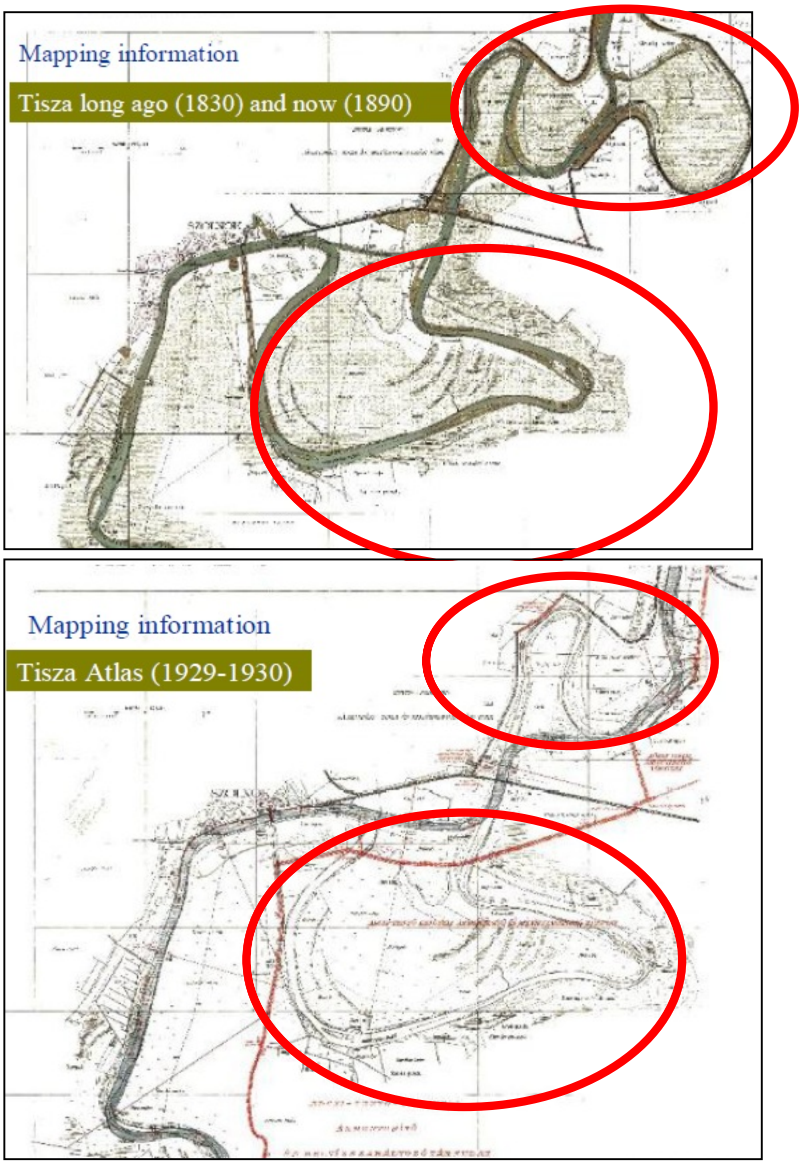

Figure 1.5. Szolnok, 'Tisza long ago and now' (above) and Szolnok, Tisza Atlas 1929-30 (below) (Tóth & Kovács, 2007).

In recent years, experts realised that the devastating consequences of floods can not be entirely prevented by technical engineering solutions (e.g. dike failures) or structural measures. Furthermore, climate change is expected to increase the frequency of extreme flood events and therefore flood impacts will aggravate. The communities and settlements affected by flood disasters do not only suffer tangible losses such as property loss and damages but also are affected by intangible effects of flooding such as casualties. An intangible effect is the negative impact on the mindset of people having lived through a flood event (Uyttendaele et.al, 2011).

Therefore, the main objective of this study was to develop a GIS tool which graphically indicates the social flood impact in flood prone areas to support decision making. This objective was accomplished through the following three steps:

- Defining indicators and a framework for the assessment
- Automating the methodology in a GIS tool
- Writing a user-friendly manual

Another objective was to apply the developed tool on the settlement Szelevény in the Körös case in Hungary. This objective implied the following facets:

- Gathering input data in a data poor environment
- Applying the GIS-tool
- Discuss the results

THE CASE STUDY: Szelevény in the Körös Corner

The pilot case study area consists of the settlement of Szelevény in Hungary. It is situated in the Körös corner flood area along the Middle Tisza River in the Black Sea catchment area (Figure 1.6 and Figure 1.7). The Körös corner flood area is affected by the Tisza River on the one hand and the Hármas-Körös River on the other hand (Figure 1.8). The Körös River flows into the Tisza River near Csongrád (Hungary) in the Körös corner flood area. The Digital Terrain Model (DTM) of the Körös corner is shown in Figure 1.9. The area between the Körös and Tisza River is almost a flat area (only 20m difference in height). Szelevény is on lower ground in comparison to other municipalities (shaded polygons in Figure 1.9) and is surrounded by ancient silted up oxbows (former meanders). The total length of the Tisza River in Hungary used to be 1419 km (in the middle of the 19th century) and it has been shortened to a length of 966 km. Because of these features, the settlement Szelevény is the most flood prone village in the area and was therefore chosen as the pilot case study.

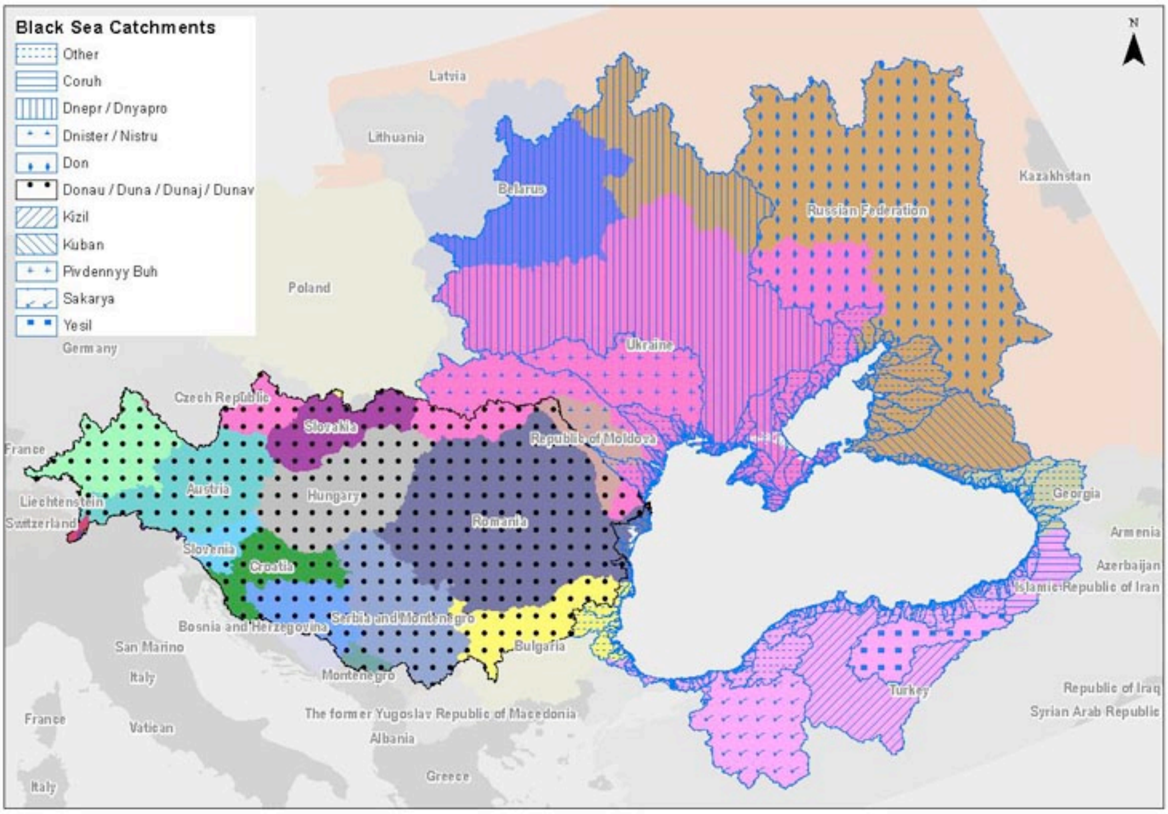

Figure 1.6. Indication of the Danube basin (block dotted area) in the Black Sea Catchment.

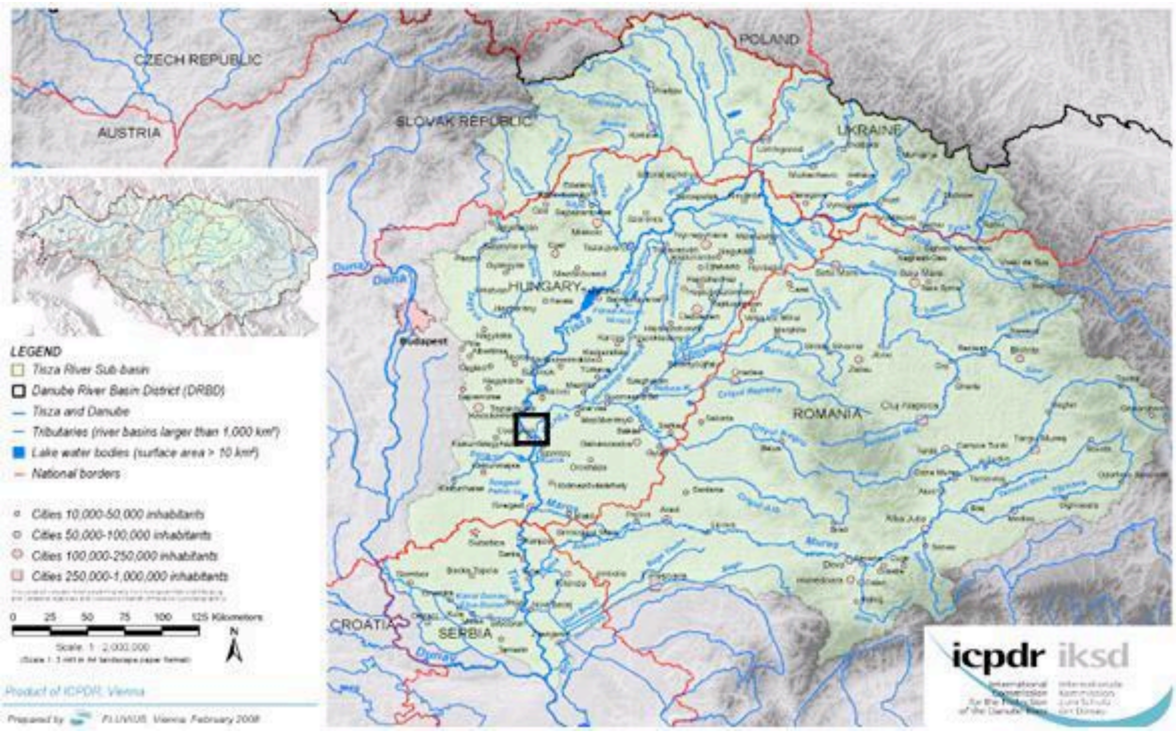

Figure 1.7. Location of the Körös corner in the Tisza sub – basin (ICPDR, 2008).

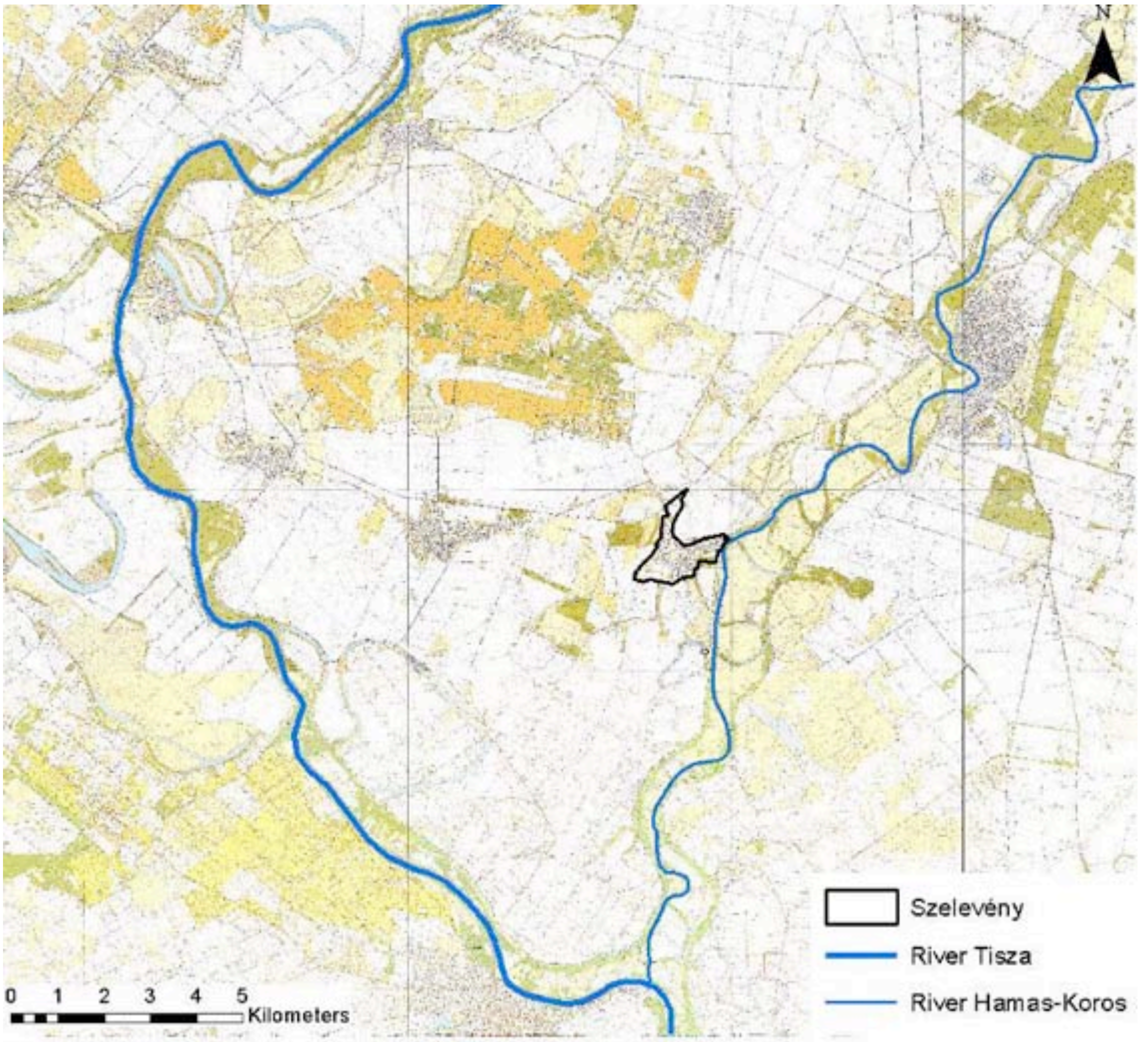

Figure 1.8. Location of Szelevény in the Körös corner area.

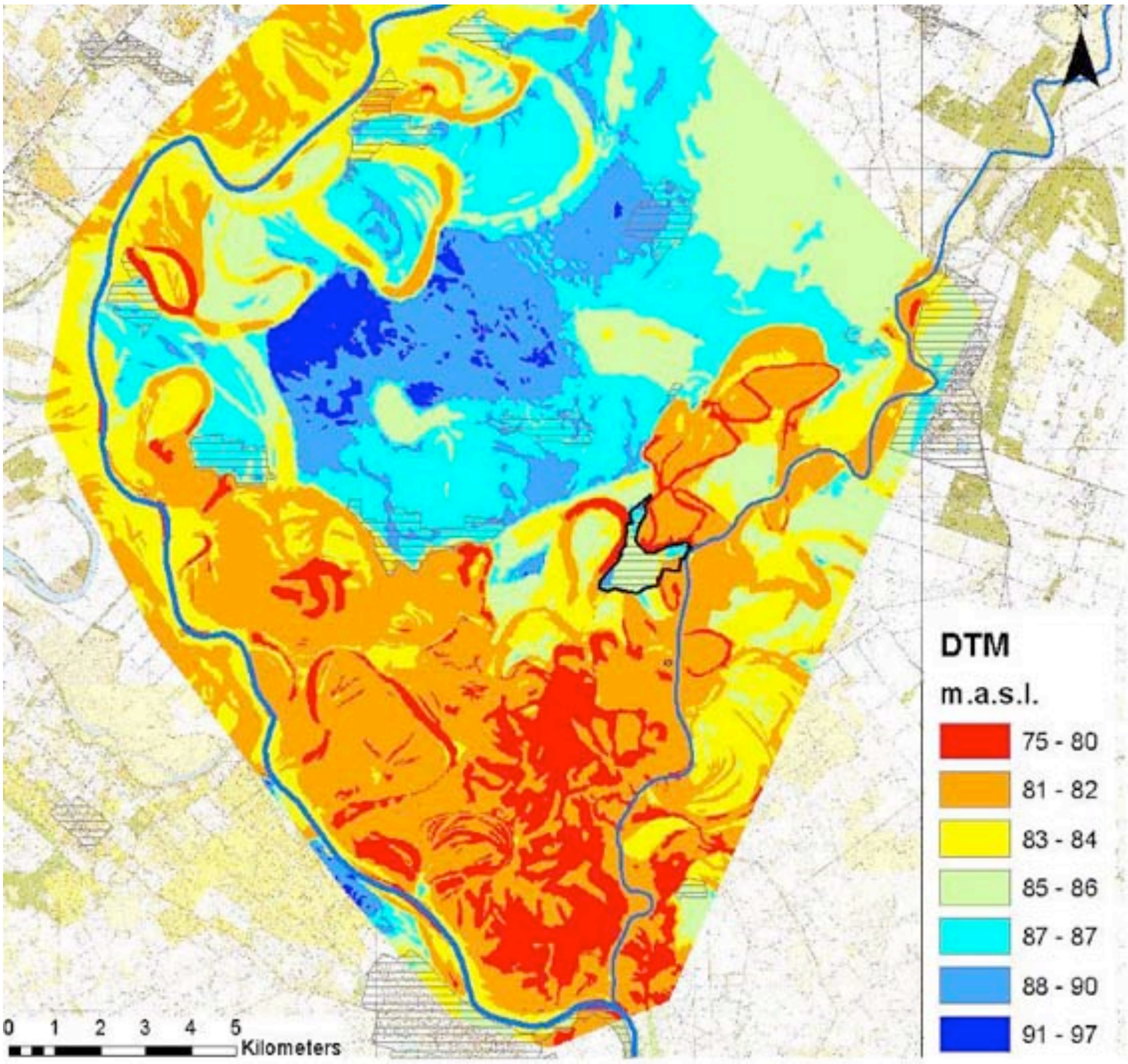

Figure 1.9. Digital Terrain Model of the Körös case (Tóth et al., 2007).

Definitions in the context of vulnerability of people towards flooding

Flood risk: This term is used to define the link between flood frequency and induced damage (Giron et al.,, 2010).

Flood hazard:

"*Flood hazard reflects the inundation intensity (such as water depth, flow velocity, rising rate, duration,…) for a number of discharge values characterized by their according frequency.*" (Giron et al., 2010)

Vulnerability:

"*Vulnerability is the susceptibility of a given population, system or place to harm from exposure to the hazard and directly affects the ability to prepare for, respond to and recover from hazards and disasters.*" (Uyttendaele et al., 2011)

Vulnerability= f(Exposure, Susceptibility, Adaptive Capacity or Resilience)

"*The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society"*(Blaikie et al., 1994 in Giron et al., 2010).

Vulnerability= f(Susceptibility/Adaptive Capacity). The vulnerability of the people rises when they are more susceptible (indicated by a high susceptibility index (Sp)) and when the society has a low adaptive capacity (indicated by a low index for the adaptive capacity (AC)) (Giron et al., 2010).

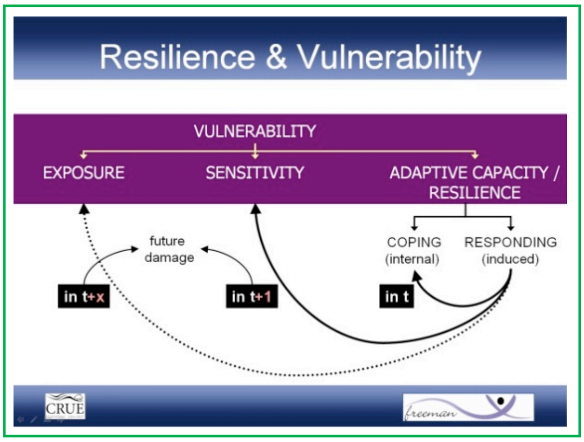

Figure 1.10. Definition and concepts of resilience and vulnerability**.**

<u>*Susceptibility:*</u>

"*Susceptibility refers to the socio-economic characteristics of people*"' (Giron et al., 2010)

"*The propensity of the people, property or other receptors to experience harm."* (Uyttendaele et al., 2011)

The ADAPT project mainly considers social susceptibility and uses several indicators to form a composed index, the social susceptibility index.

<u>*Adaptive capacity / Resilience:*</u>

"The ability of a system to adjust to changes or perturbations" (Uyttendaele et al., 2011)

"(Social) Resilience: a system's capacity to absorb disturbance and re-organize into a fully functioning system. It includes not only a system's capacity to return to the state that existed before the disturbance, but also to advance the state through learning and adaptation." (Uyttendaele et al.,, 2011)

"*The internal strength of society"* (IMDC 2011)

"The capacity of a community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure." (Steinführer 2009)

<u>*Exposure*</u>

"A parameter that indicates those populated areas that are threatened by potential flood event"' (Giron et al., 2010).

<u>Methodologies</u>

In order to find the most vulnerable spots in the settlement, it is necessary to combine the following characteristics: the level of exposure to the hazard, the susceptibility of the individuals and the adaptive capacity or resilience of the society.

A good framework for the GIS-tool was found in the ADAPT project (Giron et al., 2010). In this study, the social flood impact intensity index was quantified with the following formula:

$$SI = ft\left(F, E, V\left(\frac{Sp}{AC}\right)\right)$$

where F: Flood characteristics or Flood index

E: The exposure of the people

V: The vulnerability of the people

Sp: Susceptibility Index

AC: Adaptive capacity Index

The social flood impact intensity is a function of the flood index, the exposure and the vulnerability index (which is a function of the susceptibility index and the adaptive capacity index).

Composite indicators are used to quantify each of the elements. These are an aggregation of individual indicators into a single index which is based on an underlying theoretical/empirical model. Composite indicator construction typically passes three stages: indicator selection, score assigning, weighting and aggregation (Giron et al., 2010).

The ADAPT project aggregates the different indices according to the arithmetic mean. In this way, a high flood index, high susceptibility index and low adaptive capacity index leads to a high social flood impact intensity. Combining this with the exposure data, the result is a social flood impact intensity score per house. The higher the score, the higher the social flood impact of the flood.

In this study, the ADAPT framework is used by assessing the susceptibility index, the adaptive capacity index and the flood index. The used indicators, weights… are discussed in this section 'Methodologies'.

1. Vulnerability of people

Vulnerability of people is determined by the susceptibility of individuals and by the adaptive capacity of the society (Giron et al., 2010).

1.1 Susceptibility index

The indicator selection to define constructional and social susceptibility in the pilot case study is described in Table 1.1.

Table 1.1. Indicators selected to assess susceptibility

Characteristics	**Indicator**
Weak buildings (Constructional)	• Building characteristics: Building age, Number of floors, Height difference with the street, connected to the sewer system? • Building Structure: Bearing structure, Outer wall structure, Floor structure • Building Condition: Poor condition
Weak individuals (Social)	• Presence of elderly and sick people • Financially deprived: Job?, Educated? • Single parents and foreign born people

Scores are assigned to each indicator and are based on a predefined classification as follows:

Considered least susceptible: score = 0

Considered most susceptible: score = 1

(And sometimes one or more classes in between: score is between 0 and 1)

Some of the boundaries of these classes can be chosen by the user. For example the indicator Building Age is defined into three classes: 0-10, 11-74 and >75 years. If the building is 60 years old, the indicator Building Age scores 0.5 (middle class). But the boundaries of the classes can be adjusted. If the operator thinks a building > 60 years is the threshold, he should adjust the upper boundary. In that case the score will be 1.

The elderly, sick, unemployed and uneducated people are all considered very susceptible and have score 1. Also the single parents and the foreign born people.

The indicators are weighted according to their importance with regard to the social flood impact intensity. Ill and old people are considered highly susceptible, followed by the financially deprived and people who live in weak buildings, the single parents and immigrants. Less susceptible are the other people (Giron et al., 2010). Weights can be adjusted by the operator as well. The indicators are aggregated by a geometric mean.

1.2 Adaptive capacity index

The indicator selection to define adaptive capacity in the pilot case study is described in Table 1.2.

Table 1.2. Indicators selected to assess adaptive capacity

Mechanisms	Indicator
Social	• Social cohesion
Economic	• Insurances
Knowledge and technical	• Precautionary measures taken
Institutional	• Flood Management Plan
	• Flood Emergency Plan
	• Early Warning System
	• Reach time for emergency services

Scores are assigned to each indicator and are based on a predefined classification as follows:

Considered highly adapted: score = 0

Considered not adapted: score = 1

(And sometimes one or more classes in between: score is between 0 and 1)

Some of the boundaries of these classes can be chosen by the user. For example the indicator Reaching time is defined into three classes: standard 0-30, 31-59 and >60 minutes. If the reaching time is 40 minutes, the indicator 'Reaching Time' scores 0.5 (middle class). However, the boundaries of the classes can be adjusted. If the operator thinks a reaching time higher than 30 minutes is the threshold, he should adjust the upper boundary. In that case the score will be 1.

The indicators should be weighted according to their importance with regard to the social flood impact intensity. However, standard, they are considered equally because of the lack of knowledge to define their importance. Weights can be adjusted by the operator. The indicators are aggregated by a geometric mean.

2. Flood characteristics: the flood index

A lot of flood characteristics affect the social flood impact. Many of the characteristics depend on the return time period of the flood and can be derived from hydraulic modelling maps. Some characteristics (e.g. flood velocity, speed of water rise,…) can be left out of the equation, because they are difficult to model and are less important than the water level (Giron et al., 2010). The indicator selection to define flood characteristics in the pilot case study is described in Table 1.3.

Table 1.3. Indicators selected to assess flood characteristics

Flood Characteristics	Indicator
Flood frequency	• Flooded extent for several return periods (T200, T100, T50, T10, T5, T2)
Flood depth	• Water level in meters
Flood duration	• Duration of the flood in hours
Flood rise	• Type of flood (Flash flood or not)
Flood velocity	• Speed of the water in m/s

The more frequent a region is flooded, the higher the impact and the closer the score will be to 1. The threshold (=score 1) is reached when a region is flooded every 2 year. The indicator scores 0 when the area is flooded less frequently than T200.

The scores for the impact of flood depth are region dependant. The default settings have been derived from a case study in Hungary and were based on damage calculations on residential buildings in euro per m² per inundation depth (Tóth et al., 2008). If you have data regarding damage of residential buildings for several inundation depths, try to make your own scores. If the threshold level is reached, the indicator scores 1.

Based on literature, the social flood impact is highest when water velocity is higher than 0.5 m/s, when the water rises suddenly and when the flood event takes longer than 12h (Giron et al., 2010). In these cases, the indicator scores 1.

If data are unknown, the tool calculates the worst case scenario's (also score 1).

Based on Giron et al. (2010), the most important flood characteristic is the water level. For the other indicators, the weights cannot be set based on literature review. During the current study weighting factors were used as described in Figure 1.11. These can of course be changed based on expert judgement.

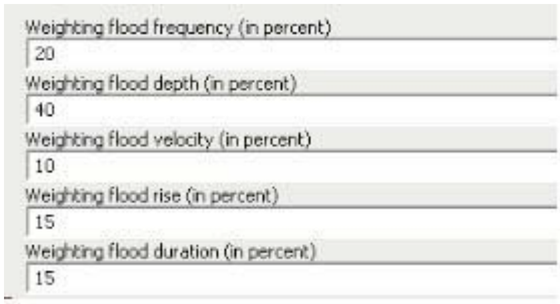

Figure 1.11. Applied weighting factors for flood characteristics in the Szelevény case study.

3. Exposure data

In this study, we want to quantify the social impact intensity of every house in a specific study area. The buildings are considered to be 'places where people live', so a valid substitute for the 'people at risk'. The exposure data are in this case a dataset of the houses.

Development of the GIS tool

The program used is ArcGis 10.0 (ArcMap), a geospatial processing program developed by ESRI. More specific, the model builder application is used to automate the different steps in the SoFLIm tool or Social FLood Impact tool.

In order to eliminate excessive information and to create a smooth working tool, the input files need to be standardized (9 standardized models). The manual describes in detail the characteristics and format of the input files. After the data is standardized, the actual calculation of the indices takes place (Susceptibility index: 1 model, Adaptive capacity index: 1 model, Flood indices for each return period: 2 models). An overview of the models can be found in Table 1.4.

Table 1.4. Different models that make up the SoFLIm tool

Step	Model name	Description
Standardizing the input data	00 Standardize Study Area	Creates a standardized file out of an empty file and the input file.
	01 Standardize Exposure 01a Standardize Susceptibility Input 01b Standardize Adaptive Capacity Input 01c Standardize FloodDepth 01c Standardize FloodDuration 01c Standardize FloodedArea 01c Standardize FloodRise 01c Standardize FloodVelocity	Creates a standardized file out of an empty file and the input file and resizes it by using the standardized study area file.
Calculation of the susceptibility index	02a Assigning Scores Susceptibility	Calculates the susceptibility index per house and creates an output feature class + a layer file.
Calculation of the adaptive capacity index	02b Assigning Scores Adaptive Capacity	Calculates the adaptive capacity index per house and creates an output feature class + a layer file.
Calculation of the flood index	02c Assigning Scores Flood Characteristics Indicators • Floodfreq1 • Floodfreq2 • Floodfreq3	This tool calculates the scores for each flood characteristic • Calculates the floodfrequency area for one return period • Calculates the floodfrequency area for all the return periods • Combines the floodfrequency areas into one file
	02c Weighting And Aggregation Flood Index	Uses the user defined weights to calculate the flood index per available return period and creates the feature classes and layer files
Deletion of files to reuse the tool	03 Delete Processing Files	Clears the files in the folder 'processing files'
	04 Delete Standardized Input Files	Clears the files in the folder 'input standard'
	05 Clear Workspace Cache	Clears the cache memory

In each model, the user is asked to fill in the required parameters. These parameters can be input files, output names, scores for a particular indicator, boundaries for the classes of indicators or weights for each indicator. This may seem an extensive list, but to make the tool widely applicable, it is necessary that the user can change the parameters at his/her will. The different functions used to build the models are shown in Table 1.5.

Table 1.5. Description of applied standard ArcMap functions

Standard ArcMap functions	**Description**
Add Field	Adds a new field to a table or the table of a feature class, feature layer, raster catalog, and/or rasters with attribute tables.
Append	Appends multiple input datasets into an existing target dataset.
Apply Symbology From Layer	This tool applies the symbology from a layer to the Input Layer.
Calculate Field	Calculates the values of a field for a feature class, feature layer, or raster catalog.
Clear Workspace Cache	Clears any ArcSDE workspace from the ArcSDE workspace cache.
Clip	Extracts input features that overlay the clip features.
Copy	Copies input data and pastes the output to the same or another location regardless of size.
Copy Features	Copies features from the input feature class or layer to a new feature class.
Delete	Permanently deletes data from disk.
Delete Field	This tool deletes one or more fields from a table, feature class, feature layer, or raster dataset.
Dissolve	Aggregates features based on specified attributes.
Get Count	Returns the total number of rows for a feature class, table, layer, or raster.
Iterate Features Classes	Iterates over feature classes in a Workspace or Feature Dataset.
Make Feature Layer	Creates a feature layer from an input feature class or layer file.
Save To Layer File	Creates an output layer file (.lyr) that references geographic data stored on disk.
Select	Extracts features from an input feature class or input feature layer, typically using a select or Structured Query Language expression and stores them in an output feature class.
Select Layer By Attribute	Adds, updates, or removes a selection on a layer or table view based on an attribute query.
Spatial join	Transfers the attributes from one feature class to another feature class, based on the spatial relationships between the features in the two feature classes.
Union	Computes a geometric intersection of the Input Features.

A screenshot of the SoFlIm tool and Weighting and Aggregation model are shown in Figure 1.12 and Figure 1.13. The result of the tool is a map with feature layers with a predefined symbology for each of the indices.

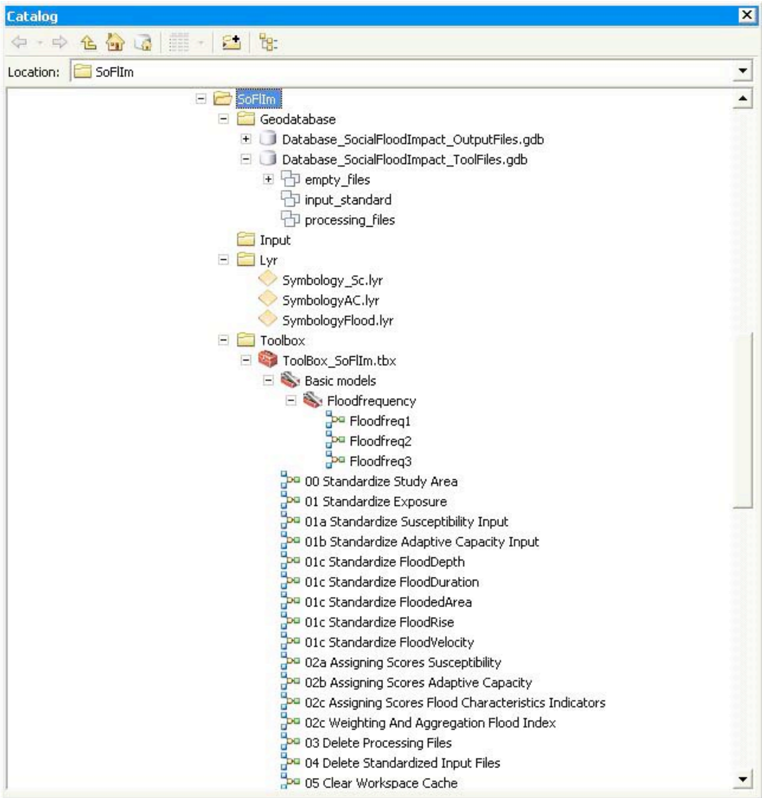

Figure 1.12. Screenshot of SoFlIm tool.

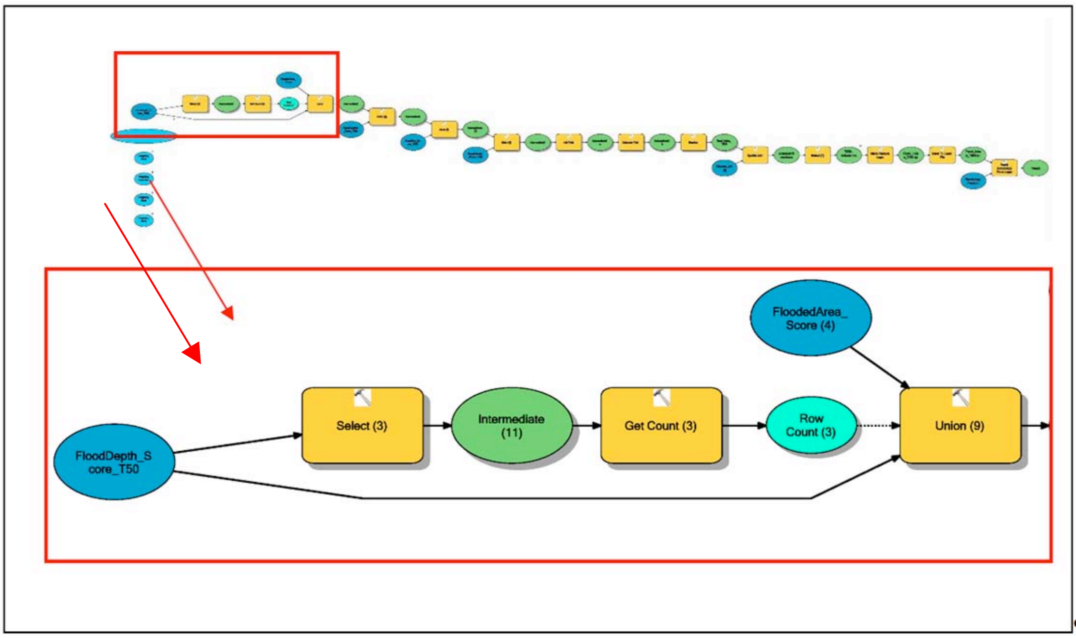

Figure 1.13. Weighting and aggregation flood index (02c part of the model).

Application of the GIS tool to Szelevény

1. Data Collection

The most challenging aspect of the application of the GIS-tool to Szelevény was to gather the required input data.

A lot of information has been found in the report 'Vulnerability Analysis in the Körös-corner flood area along the Middle - Tisza River' (Tóth et al., 2008), especially the required information to calculate the flood index for T_{200}, T_{100} and T_{50}. However, to be able to calculate the susceptibility index and the adaptive capacity index, additional research was necessary. Therefore, a questionnaire was developed and field work was carried out in April 2012 during one week.

1.1 Exposure data

The shapefile containing the delineation of the houses was developed based on Google Earth and updated during the field work (Figure 1.14).

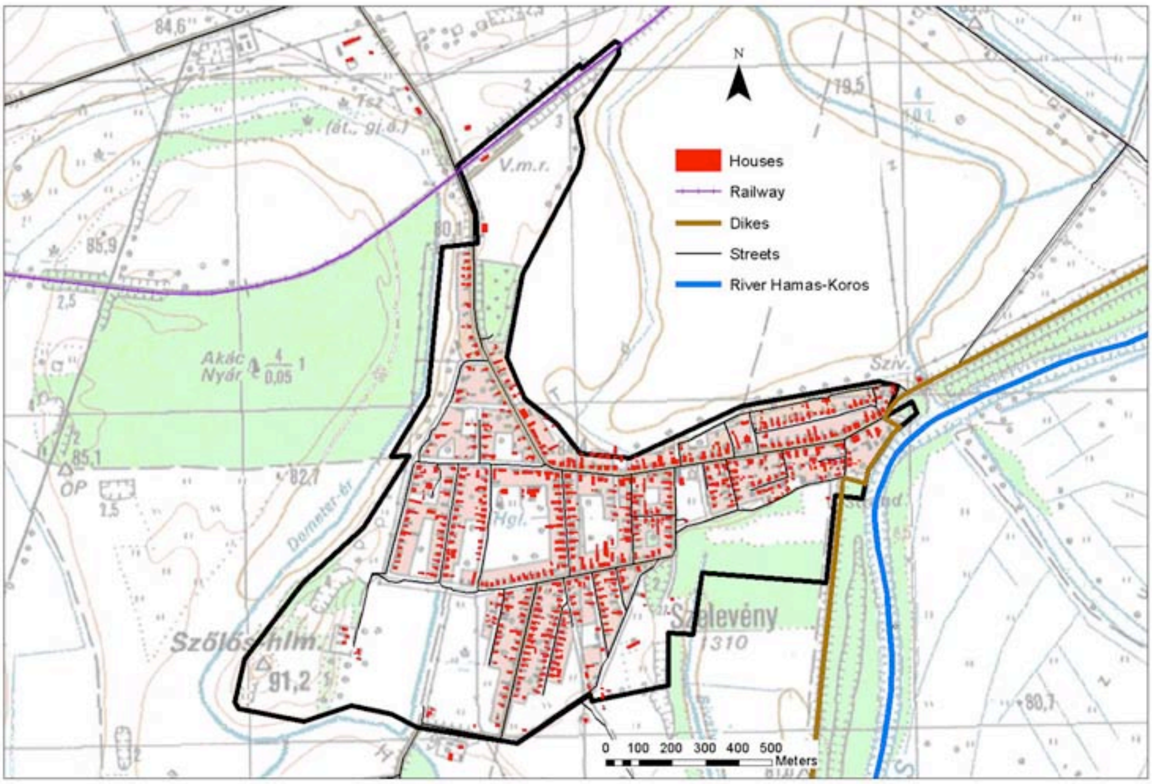

Figure 1.14. Basic map of Szelevény (indicating the houses, Google Earth and field work 2012).

1.2 Flood characteristics: the flood index: data collection

The flooded area and flood depths for T_{200}, T_{100} and T_{50} have been derived from the DTM 5x5m of the Körös corner area (Tóth et al., 2008). A dike breach was assumed (Tóth et al., 2008) so the flooding will appear suddenly in the whole area for T_{200}, T_{100} and T_{50} so immediately a static situation with a complete flooding zone is reached. Unfortunately, we did not have any data about the water velocity. From the study carried out by Tóth et al. (2008) it can be derived that the flood event will last longer than 12 hours for T_{200}, T_{100} and T_{50}.

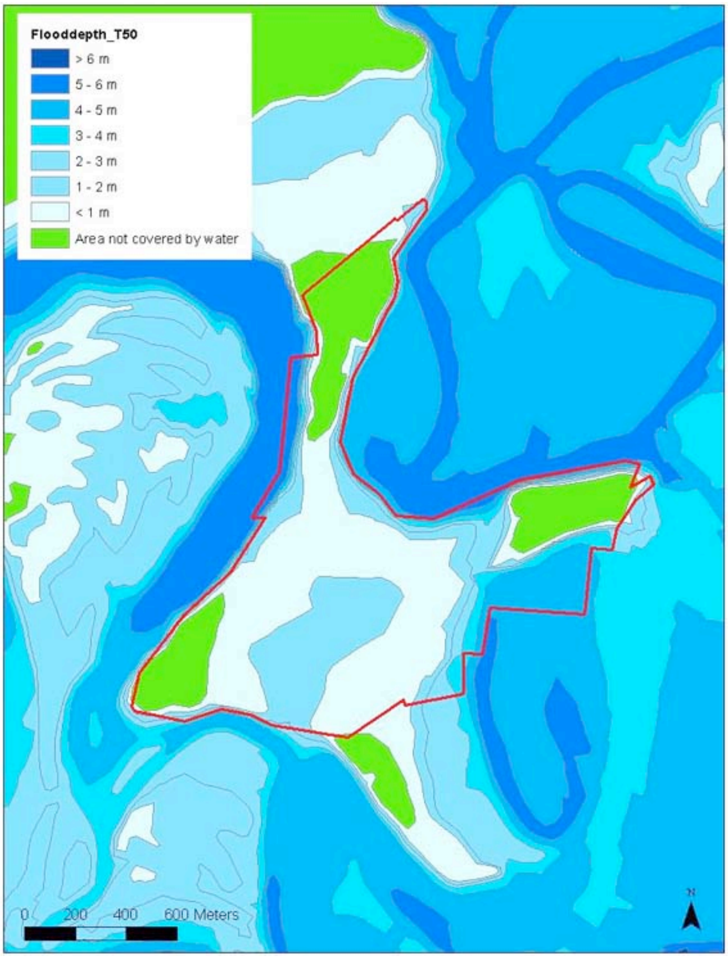

Figure 1.15. Flood depths for a storm with return time period of 50 years (theoretically) (Tóth et al., 2008). Red line delimits Szelevény village.

1.3 Susceptibility index: data collection

The characteristics of the buildings were gathered during intensive field work. A part of the dataset can be found in Table 1.6. Characteristics of the individuals were mainly gathered based on interviews.

Figure 1.16. Pictures of a typical old house (left) and a more recent house (right).

Table 1.6. Characteristics of housing in Szelevény (field work 2012).

Number	Building Age	Number of floors	Height difference with the street	Connected to the sewer system?	CONDITION	Bearing structure	Outer wall structure	Floor structure
0	30	1	2	Yes	poor	bricks	Bricks	Unknown
1	60	1	0	Yes	poor	clay	Clay	Unknown
2	50	1	1	Yes	good	clay	Clay	Unknown
3	50	1	1	Yes	poor	clay	Clay	Unknown
6	50	1	1	Yes	good	clay	clay	Unknown
7	30	2	2	Yes	good	bricks	clay	Unknown
9	40	1	1	Yes	good	clay	clay	Unknown
10	40	2	2	Yes	good	bricks	clay	Unknown

1.4 Adaptive capacity index: data collection

The required data for defining the indicators of adaptive capacity (social cohesion, insurance, precautionary measures taken, Flood Management Plan, Flood Emergency Plan, Early Warning System, Reach time for emergency services) have been deduced mainly from interviews. The flood risk management is quite well organized and a state of the art Early Warning system exists.

Results and discussion of the results

As mentioned before, the social flood impact intensity is a function of the flood index, the exposure and the vulnerability index (which is a function of the susceptibility index and the adaptive capacity index). The developed SoFLIm tool generates feature classes and feature layers with a predefined symbology.

The **adaptive capacity index** for the village can be observed in Figure 1.17. Because of the scale of this study, this index is the same for the entire settlement. It is a small village, and these indicators are organized on the county level (e.g. early warning system). Hence no spatial variation was observed for the pilot case study. This index could be compared in time for the Szelevény village or with other locations. The value of the adaptive capacity index is high. From the experiences and interviews during the field work, it can be concluded that the social cohesion in the settlement is very strong and that there is a high level of preparedness. There is a clear emergency plan and the inhabitants know exactly what to do in case of a flood alert.

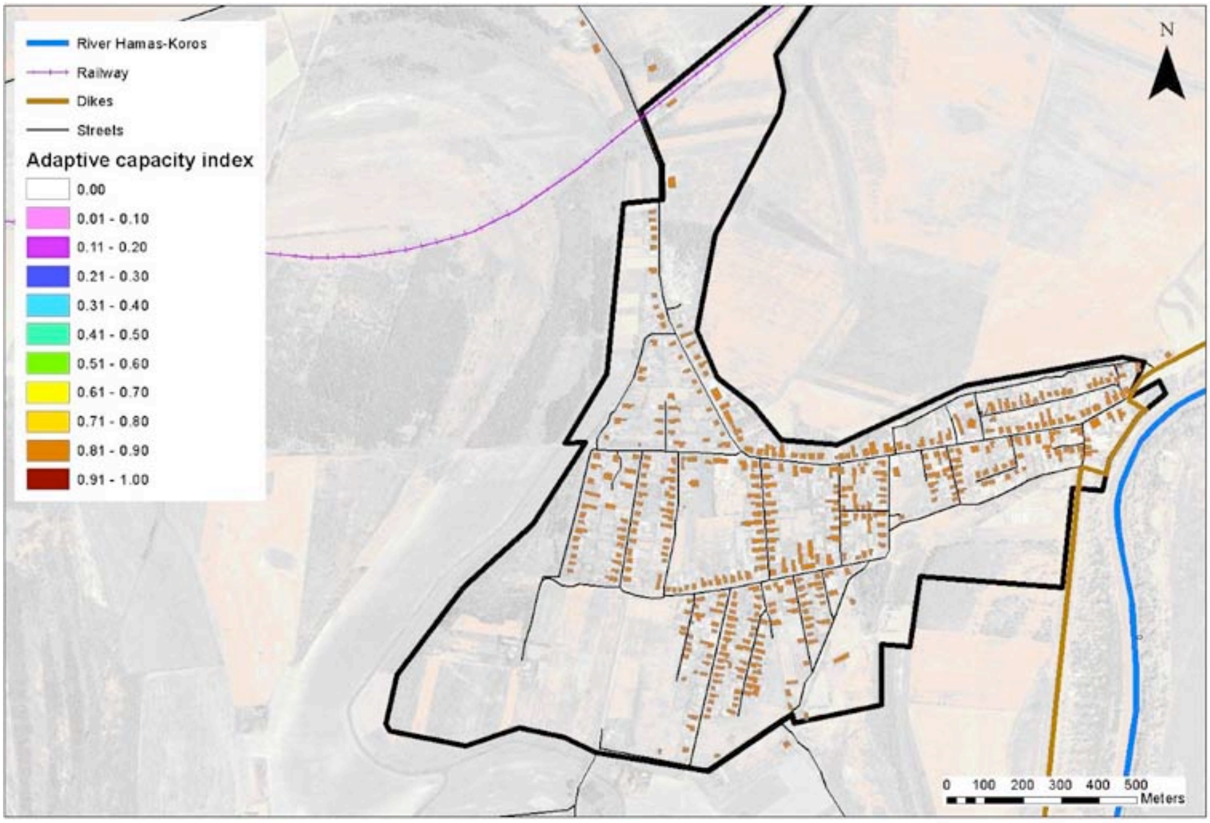

Figure 1.17. Adaptive capacity index for Szelevény village.

The **susceptibility index** is more differentiated for the Szelevény village (Figure 1.18). This can be explained by the high variation in building conditions. In general, the houses can be considered as old and suboptimal state. Moreover it is important to mention that the common building material (being clay) and the housing foundations (in many cases a solid foundation is absent) contribute to high average susceptibility, especially in the South of the settlement. There are quite some houses with a height difference between the street and the entrances, which limits the susceptibility somewhat. The strongly coherent society (adaptive capacity) is partially countered by the high average age of the population. Most people require help in case of evacuation, which also leads to a higher susceptibility.

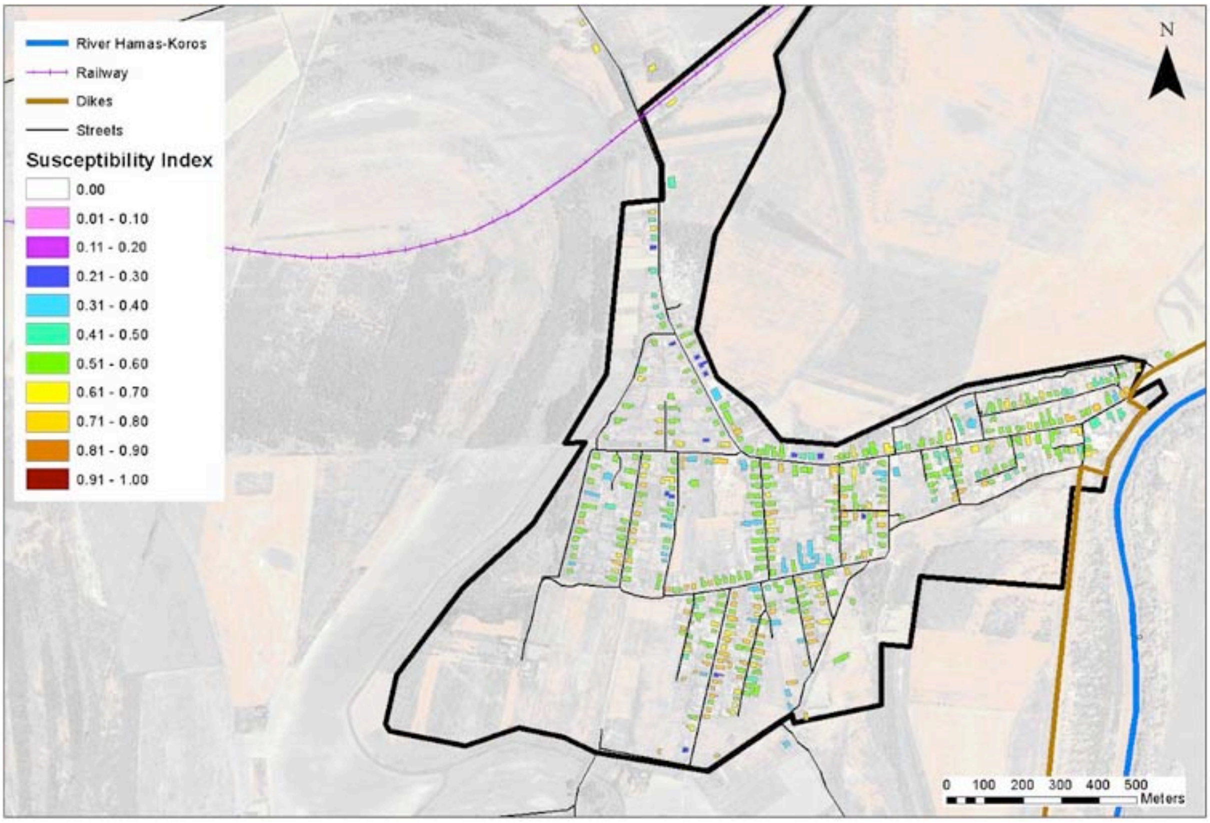

Figure 1.18. Susceptibility index for Szelevény village.

The flood indices indicate that the highest regions of the village, located in the East and North, are not flooded up to a return time period of T200. Witnesses of people in these parts confirmed this and stated that no problems regarding flooding and water damage occur.

Combining the susceptibility index and the adaptive capacity index with the flood indices for T200, T100 and T50, results in the Social Flood Impact Intensity Index (Figure 1.19 till Figure 1.21). It can be concluded from these maps that the social impact of floods in Szelevény is very high, especially due to the high flood index. However, these results are more valuable when they can be compared to the results of other settlements.

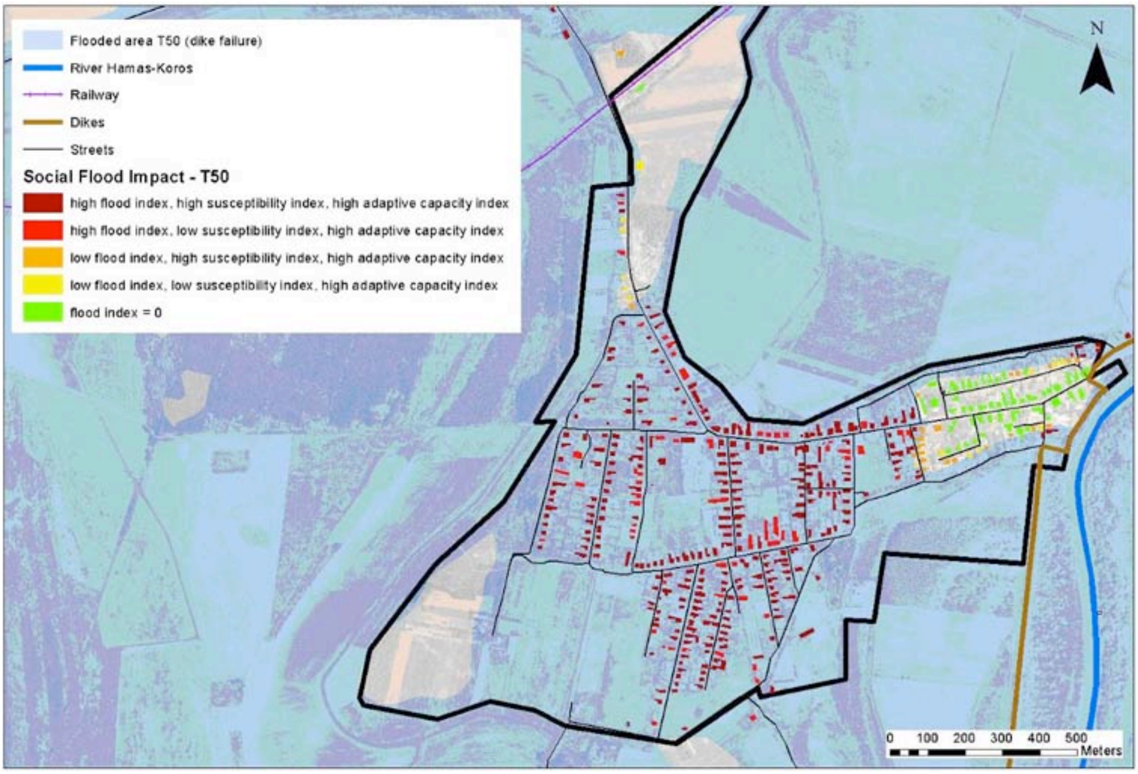

Figure 1.19. Social Flood Impact for Szelevény village (return time period of 50 years).

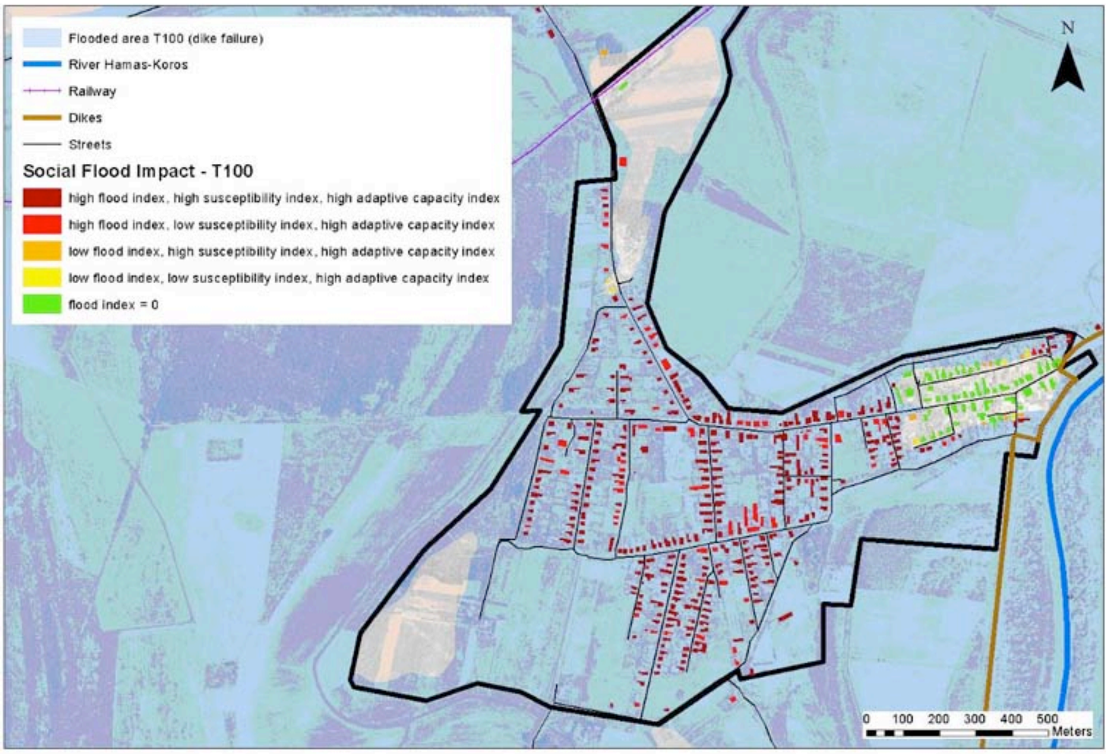

Figure 1.20. Social Flood Impact for Szelevény village (return time period of 100 years).

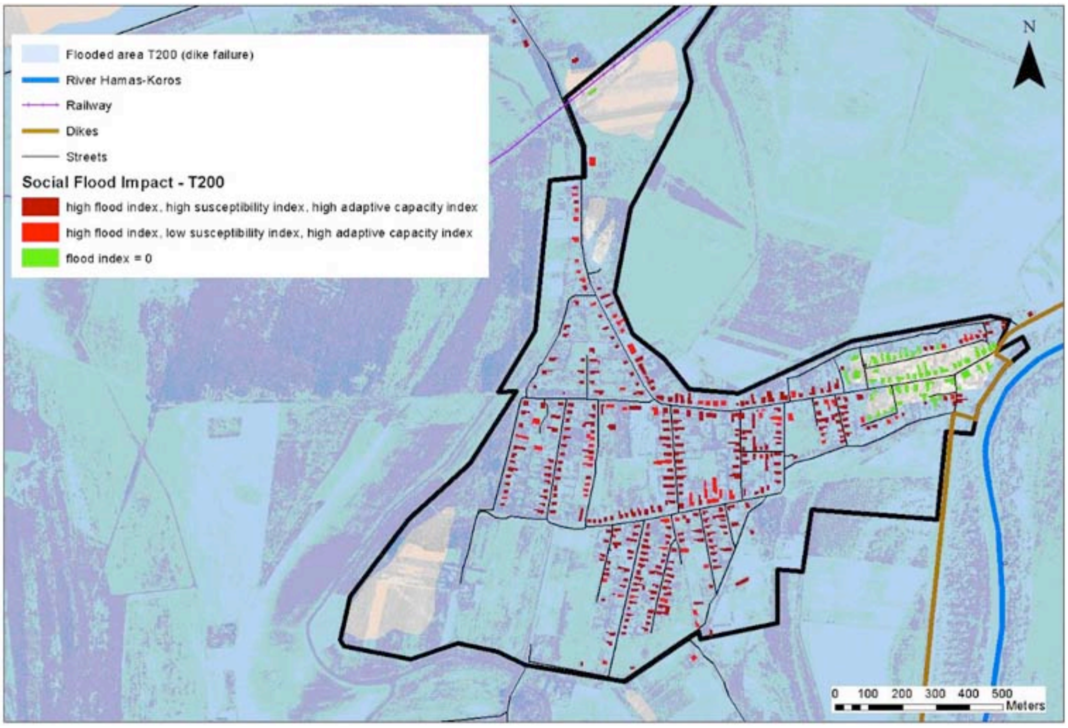

Figure 1.21. Social Flood Impact for Szelevény village (return time period of 200 years).

A combination of structural and non-structural measures that limit flood risk should be put in place. To reduce the social flood impact, both the flood index and the vulnerability should be reduced.

In order to reduce the Flood index, it is very important to understand that if there is a dike breach, almost the whole village is destroyed. Therefore, reinforcing the dikes is a measure with highest priority. Now, the risk of displacement is high. Besides reinforcing the dike, retention reservoirs should be built. Two such reservoirs already exist and two are in the planning phase. Such a retention reservoir nearby Szelevény would lower the inundation risk.

In Figure 1.22, houses in Szelevény with the highest social flood impact (T_{50}) are indicated in black (very high flood index, high susceptibility index, high adaptive capacity). The first measures to reduce the susceptibility should be taken for these people. Houses in unflooded areas (flood index = 0) with a high susceptibility are not considered to be a problem.

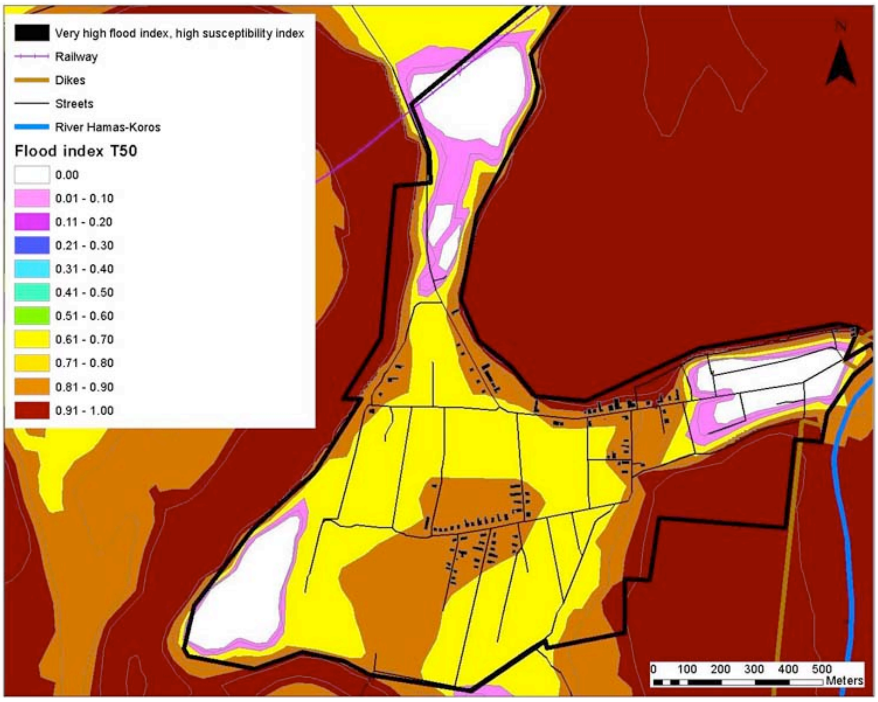

Figure 1.22. Location of houses (black) with highest social flood impact (return time period of 50 years).

The adaptive capacity of the settlement Szelevény is quite high, but improvements can always be made. An Early Warning System to discover cracks in the dike would be very good. Nowadays guards need to walk down the entire dike from Kunszenmartón all the way to Csongrád and control the dike visually. However, visual observation cannot assess sufficiently dike stability or the probability that breached would occur. A tool was created, called 'live dijk' (http://nederlandvanboven.vpro.nl/afleveringen/water-video.html#video> Live dijk), where they can look into the dike by placing some gauging points / sensors in the dike. Just by looking at an Ipad, one can see and control the status of the dike (inside and outside).

Conclusions and Recommendations

Regarding the **development of the GIS tool,** the following can be concluded: The basis of the methodology is good but…some improvements can be made.

For example, more research is necessary to define all relevant indicators and especially to refine their scores and weights. Standardized scores and weights are required to be able to compare outputs on regional scale.

Furthermore, the tool is a basic design and still holds a lot of potential for improvement or expansion. It is developed to be extended easily. While making this tool, limitations of the application Model builder and bugs appeared. Therefore, conversion of the tool from model builder to python (arcpy) would make it more flexible. With conversion from ArcGIS to an Open Source GIS, the tool could be applied by any organisation.

Regarding the **application on Szelevény,** the following can be concluded: (1) The availability of data is crucial to have useful results. (2) It is also very important to interpret the results as relative values instead of absolute scores. If the analysis could be done for different villages, it would be possible to compare the results space and in time. This could be very useful to help and evaluate decision-making on the right scale. Potential help and funds could be delivered to those settlements who will suffer the most or in other words, who are more vulnerable to flooding.

1.3.2.2. Braided river system simulation based results of design flood estimation for the Koros Tisza confluence.

Introduction

Hydrologists involved with operational stream forecasting and flood control may be interested in possible future scenarios of flood events. This may help them prepare for events that has not yet been observed in the past for which measurements are available but nonetheless can be expected in the future. While statistical analyses of e.g., annual maxima, may give information on the return period of floods with different magnitudes, they do not provide information on the possible time-sequence of the expected flood event. Such information may encompass duration of different water levels during flood, the speed at which stream levels may rise or the flood may recede, all of which potentially influencing how flood protection works ought to be planned and organized.

Since adequate information of precipitation over the watershed is often lacking, and even when it is available, not much may be known of the effective precipitation that actually forms the flood event, stochastic techniques that do not require information on precipitation may be practical to pursue.

The multivariate, seasonal streamflow generation algorithm (Szilagyi et al., 2005; Balint et al., 2005) uses components of the shot noise models in a Markov-chain based approach together with a conceptual framework describing flow recession without the need for information of precipitation. It is built around the concept of conditional heteroscedasticity originally established in the ARCH models (Engle, 1982) of time series analysis when it is assumed that the noise term is not independent of the process to be modelled nor it is identically distributed.

After developing some of these studies, the following station network was proposed (Table 1.7).

Table 1.7. Station network lower Tisza and tributaries.

HYDRA code	Station	River	River/ chainage km	Type of station Y- yes; N – no; P - possible		
				Upstream	Routing	Target
542035	Novi Sad	Danube	1255,1	Y	N	N
444229	Szolnok	Tisza	334,6	Y	N	N
444230	Csongrád	Tisza	246,2	N	Y	Y
444371	Gyoma	H-Körös	79,2	Y	N	N
444571	Békéssztandrás	H-Körös	47,48	N	Y	P
444372	Kunszentmárton	H-Körös	21,1	N	Y	P
444574	Mindszent	Tisza	217,7	N	Y	Y
744622	Arad	Mures	97,0	Y	N	N
444396	Makó	Maros	24,5	P	Y	N
444231	Szeged	Tisza	173,6	P	Y	Y
544020	Senta	Tisza	123,4	P	Y	Y
544030	Novi Becej	Tisza	65,1	N	Y	Y
544040	Titel	Tisza	9,5	P	Y	P
542045	Zemun	Danube	1172,9	P	Y	N

Application of the proposed scheme

The proposed combination of the upstream hydrograph generation and flood routing scheme is foreseen for national use in Hungary, as well there are possibilities to use wider in the Danube Basin.

Data requirements

Three types of hydrological stations compose the simulation scheme, with different data needs, namely:

- Upstream stations for Markov Chain Monte Carlo (MCMC) type of simulations of daily discharge series:

  Long observed daily discharge series are required with minimum length of 30-50 years.

- Flood routing stations:

  Observed 2-10 years of discharge and water level series, preferably covering the entire range of observed water levels, discharges, i.e. high and low water years. Additionally rating curve representing present day or designed future conditions. In case of sufficient station density observed water level time series can also be utilized to create "interpolated" rating curves and/or discharge series.

- Target stations, selected flood routing stations, which simulated discharge and/or water level "design" hydrographs are used as input and boundary conditions for hydrodynamic models:

  Data requirements are as at flood routing stations – minimum requirement. To check and validate flood frequency estimates received for simulated series additional long observed daily discharge series are beneficial (at least 30-50 years). In most cases monthly (or at least annual) maxima are sufficient.

The overall scheme for the Danube Basin and the Tisza scheme

A scheme of the proposed station network for the lower Tisza and tributaries is presented on Figure 1.23 and Table 1.7. Downstream boundary conditions can be simulated directly to Titel station, while the other option is based on Danube stations, either or both on Novi Sad and Zemun.

The actually implemented version applied some modifications to the generally proposed scheme. The Koros – Gyoma upper boundary was simulated as the resulting flow from Crisul Alb/Feher Koros and Crisul Negru/Fekete Koros with a stochastic additional value (to represent those tributaries directly not accounted Crisul Repede/Sebes Koros and Barcau/Berettyo).

Upper and lower boundary observed series statistical analyses are given in Annexes. Tisza Szolnok, Szeged and Senta; Crisul Alb – Chisineu Cris, Crisul Negru – Beius, Maros- Mako stations annual maxima and flood peaks over arbitrarily set thresholds were analysed. General Extreme Value (GEV) analyses for annual maxima is performed while the peaks above thresholds are investigated by fitting the Generalised Pareto Distribution (GPD).

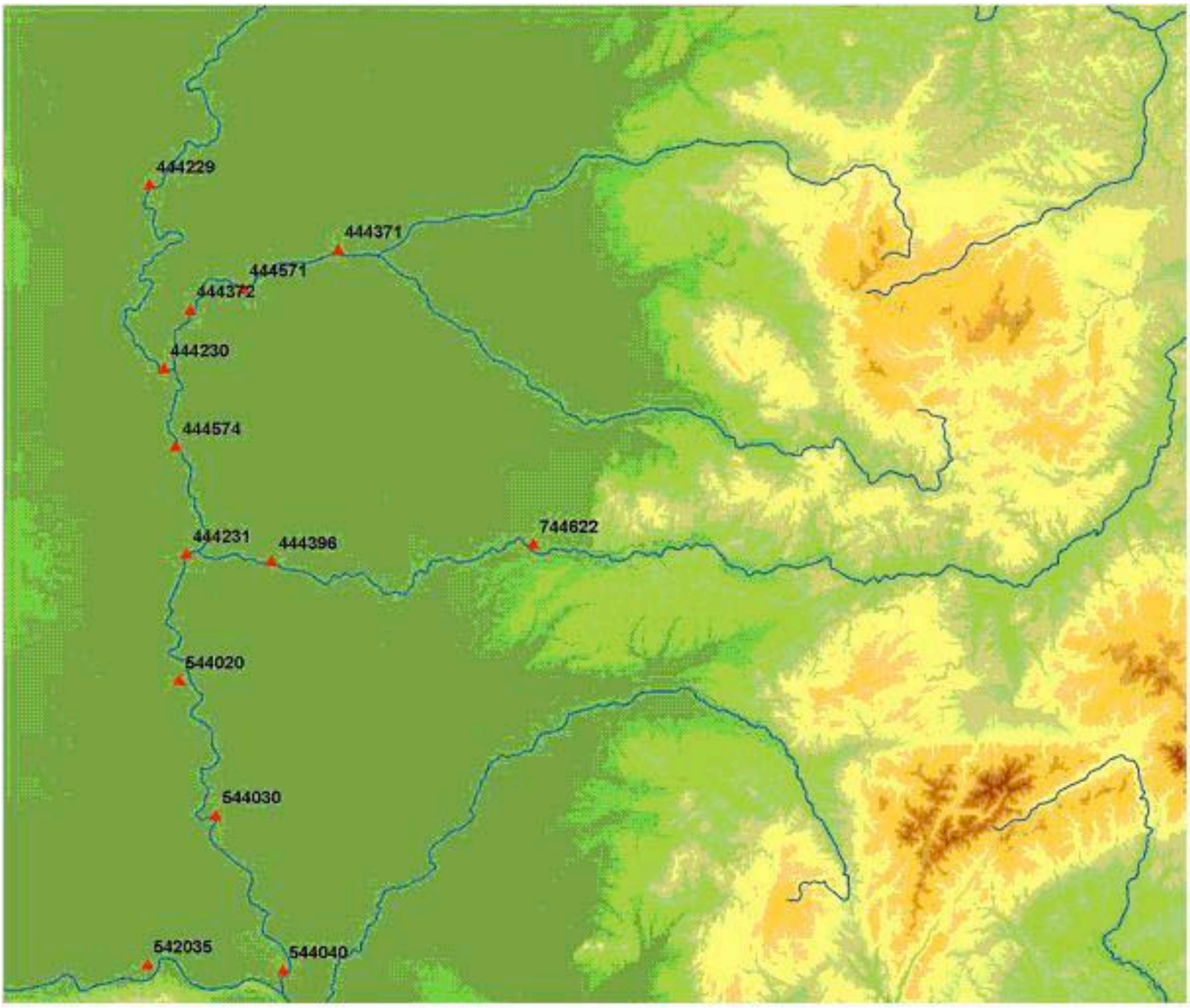

Figure 1.23. Scheme of the proposed station network for the lower Tisza and tributaries.

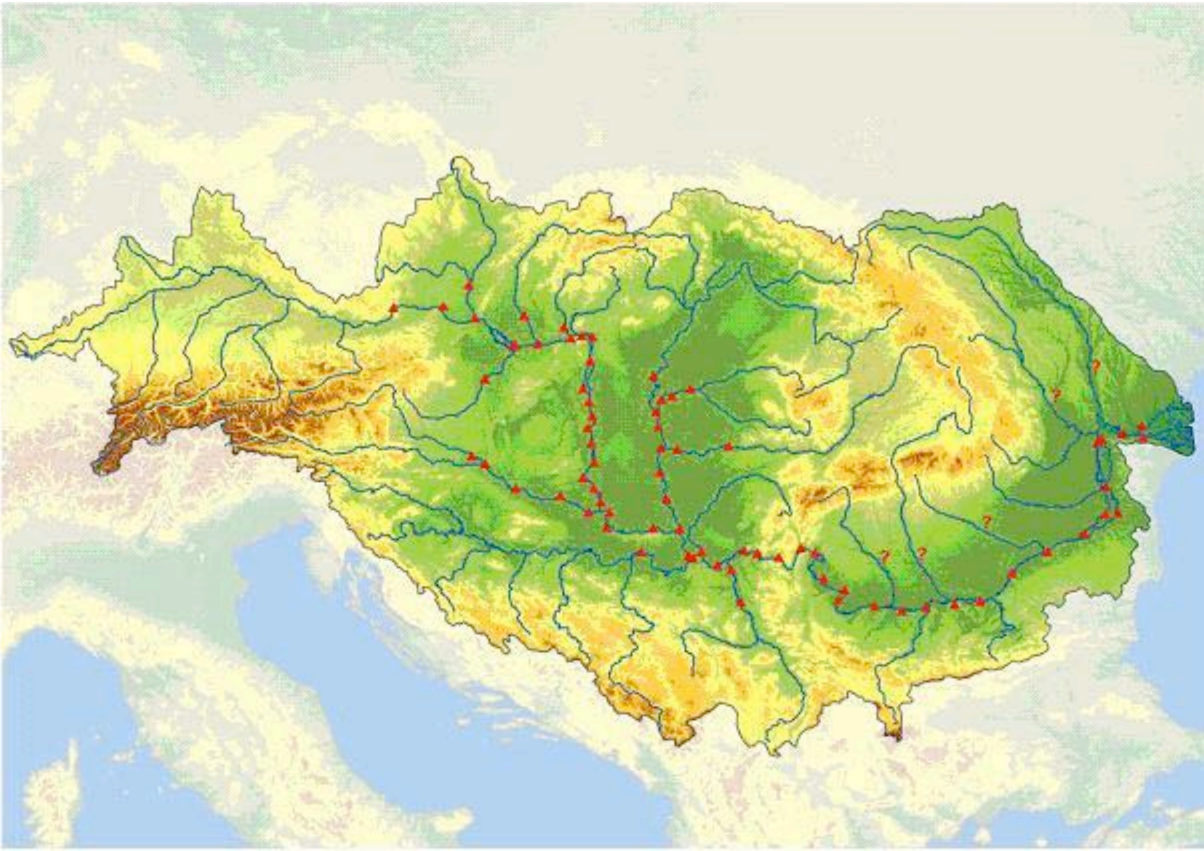

Figure 1.24. General scheme of the proposed station network for central and lower Danube reaches and tributaries.

Modelling results

The Tisza River is the largest tributary of the Danube considering its watershed (Figure 1.24). Besides the gauging station of Szolnok at the Tisza River, three additional sites on different on Körös and Maros tributaries of the Tisza were included in the study.

At least 50 years of daily instantaneous flow-rate values were employed for all four gauging stations for statistical inference. Tisza at Szolnok shows that a wet-to-wet transition has the highest likelihood in spring, which comes from two sources: (a) it is the season of most abundant precipitation in the region; and (b) it is the time of year when melting snow in the Carpathian Mountains feeds the streams, occasionally (especially when combined with rain) causing major flooding in the region. The positive diurnal increment values at Szolnok were fitted with Weibull distributions for each season and randomly generated using those distributions. For each increment a W value (Eq. [2]) was added, with optimized values of a and b.

The asymmetric shape of the observed hydrographs is well conserved in the generated data (Figure 1.25). The annual change in the median values (i.e. elevated water levels in spring, low flows in autumn), as well as the skewness of the distributions are clearly maintained in the Monte-Carlo generated daily flow rates.

Simulation of tributary flow differs from the main channel one only in the application of a polynomial regression between tributary and main channel diurnal increments during wet spells of the main tributary in place of a Markov approach of state transition probabilities.

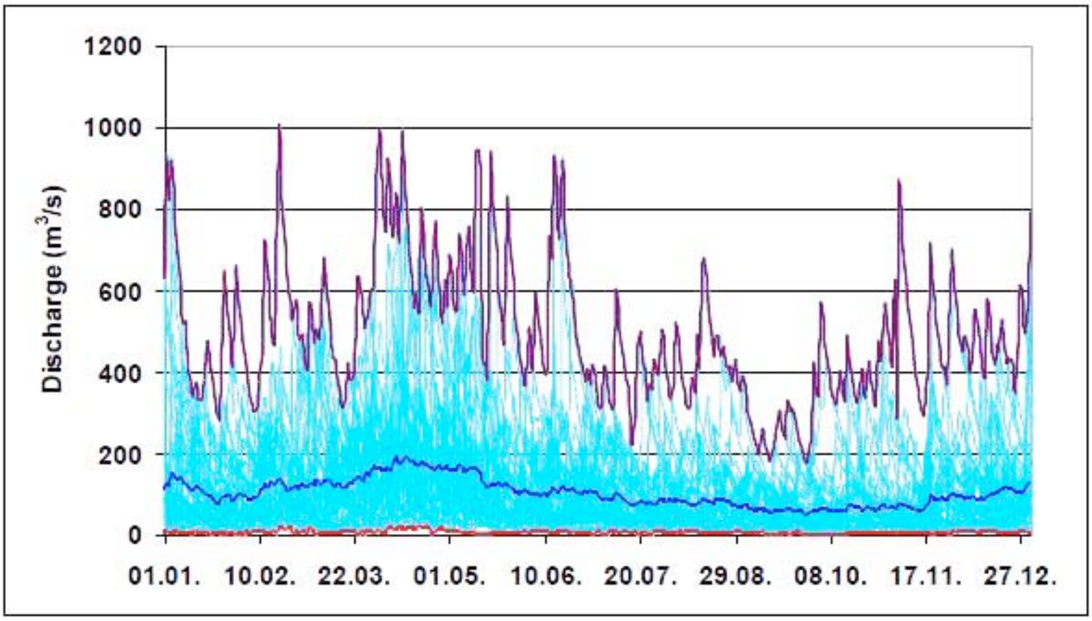

Figure 1.25. Example of seasonal fit of a sample 50-year simulation Maros-Mako.

The generation of the design flood hydrograph for the Tisza – Koros confluence is illustrated by the series of hydrographs resulting from the 3000-year long simulations representing at least 30-fold longer series than observed. The selected 30 largest flood extremes can be clustered into two groups: cumulative but shorter flood waves and multiply "1970-type" of floods.

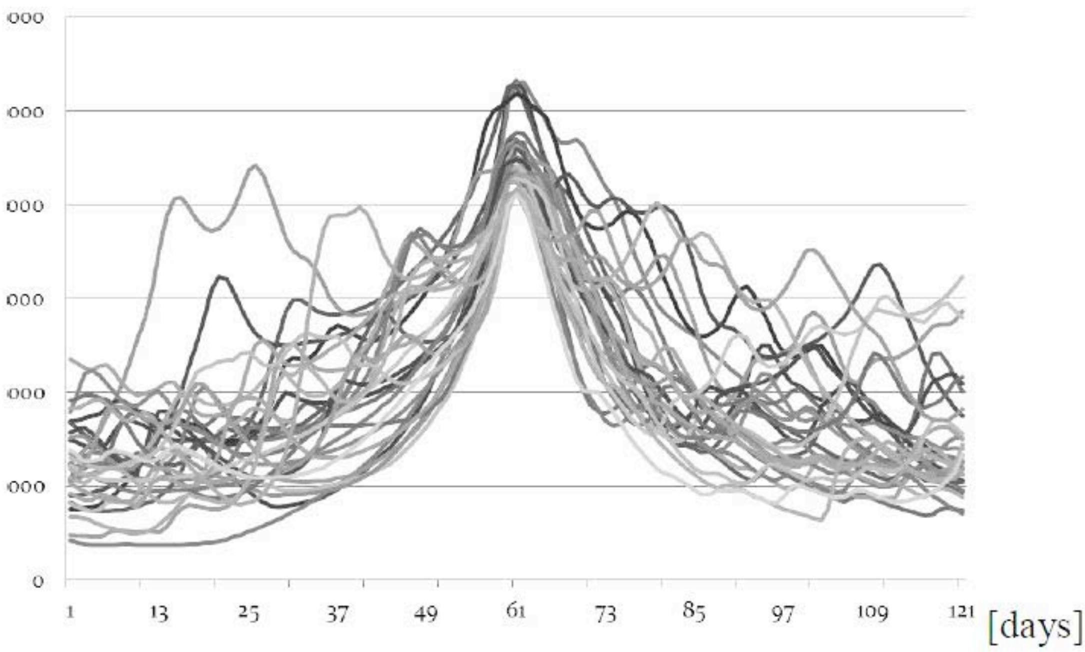

Figure 1.26. Example of simulated extreme floods sampled 30 highest values for Tisza – Csongrad (near the Koros mouth).

Conclusions

A hybrid, seasonal, Markov chain-based model combined with Discrete Linear Cascade Model flood routing is used for daily streamflow generation in the braided river system of the Tisza. The simulation technique applied uses stochastically generated diurnal increments of the rising limb of the main channel hydrograph combined with fitted, seasonally varying distributions in combination of an additional noise term whose standard deviation depended linearly on the actual value of the generated increment at the principal upstream station. Increments of the ascension hydrograph values at the tributary sites were related by second-order polynomials to the main channel ones together with an additional noise term whose standard deviation depended nonlinearly on the main channel's actual increment value. The recession flow rates of the tributaries as well as of the main channel were allowed to decay deterministically in a nonlinear way. Three thousand year of simulation was performed for the selected river network using the simplified hydrodynamic module. The Koros-Tisza confluence is represented by the Tisza – Csongrad station where extreme flood hydrographs were analyzed. It is expected that simulation results revealed extreme coincidences not observed directly but resulting from the observed type of flood generation patterns.

In summary it can be stated that by the application of the proposed hybrid, seasonal Markov chain-based approach of daily flow simulation at multiple catchment sites it is possible to generate arbitrarily long time series of daily flow rates that fairly well preserve basic long-term (mean, variance, skewness, autocorrelation structure, cross-correlations) statistics as well as short-term behavior (asymmetric hydrograph) of the original time series. The approach is centered around the concept of conditional heteroscedasticity which means that the noise term of the stochastic model applied is not independent of the process to be modeled, neither is identically distributed. The upstream simulation model has altogether 9 parameters (in a seasonal formulation) for the main channel site to be optimized, and 6 additional parameters for each gaging station to be included. While the described approach is very simple, optimization of the parameters may require some effort from the modeler while the flood routing remains a simple task.

1.3.2.3. Analyses of snow resources based seasonal prediction of Danube and Tisza spring flow and flood peaks

Introduction

Accurate estimation of the volume of water stored in the snow pack and its rate of release is essential to predict the flow during the snowmelt period. For an estimation of the snowmelt, the information on snow cover depth and water equivalent is a pre-requisite. In the mountainous regions little information relating to meteorological and physical factors affecting runoff is available. Snowmelt is not measured quantitatively but must be estimated (Clark et al., 2009). The factors involved in the computation of snowmelt are so numerous that it is practically impossible to account for all of them. Some of them are not regularly measured or are available only on experimental sites. An important variable in the mountainous watersheds during the snowmelt season is the aerial extent of the snow cover.

Observation and modelling based estimation of the snowpack

The HOLV snowmelt model is developed by the Hungarian National Hydrological Forecasting Service (VITUKI OVSZ/NHFS). The model originates from the early 80's (Bálint & Bartha, 1982) and it is under continuous development (Bálint & Gauzer, 1994), while recently its distributed version over a grid with 0.1 degree resolution is in use to assess snow accumulation and ablation. The snowmelt model has a flexible structure; it is able to change its own structure in function of data availability. In case when only precipitation and air temperature data are available temperature index method is used. When also other data are accessible (cloudiness, dew point, wind speed) using of energy balance model is to be preferred. If there are suitable data available for calculation of the energy terms, the energy balance method can be applied. These simulations appear to provide an adequate representation of snow climatology. While the use of more physically-based energybalance methods may help to improve the simulations (Etchevers et al., 2004), such methods have larger data requirements, and it is unclear whether the improvements so obtained would be significant given the uncertainty in the model input data. Otherwise the degree-day or temperature index method can be used. The temperature index is considered time-variable, as a consequence of seasonal changes of the solar radiation values corresponding to the same air temperature, and even of changes of the albedo of the snow surface. The calculations need to be carried out with a daily time step. Since the application presumes conditions free of snow when started, it is proper to begin the calculations at the time of the year when the catchments are covered with minimum quantity of snow.

HOLV snowmelt model is designed for daily use. It can be run every day after receiving the morning datasets and calculates all the values for the last 24 hours. If calculations are skipped on a certain day, they have to be done subsequently. The calculations need to be carried out with a daily time step. Since the application presumes conditions free of snow when started, it is proper to begin the calculations at the time of the year when the catchments are covered with minimum quantity of snow.

The HOLV snowmelt model has a flexible structure, it is able to change its own structure in function of the data availability. In case of availability precipitation and air temperature data only temperature index method is used, when further data are accessible too (cloudiness, dew point, speed of wind), using of energy balance model is to be preferred.

Application of energy balance and temperature index approaches

The energy balance of snowcover:

E_o-E_z = (1-A) E_{sw} + E_{lw} - E_e + E_s + E_l + E_c + E_g

where:

- E_o - the total energy absorbed/emitted by the snow surface [J/m^{2}s]
- E_z - the total flux of energy across the boundary between the snow and soil [J/m^{2}s]
- E_{sw} - the energy arriving onto the snow surface from short wave radiations [J/m^{2}s]
- A - the albedo of snow which expresses the fraction of the incoming short wave radiation, that will be reflected by the snow surface back to the atmosphere [J/m^{2}s].
- E_{lw} - the atmospheric long wave radiation [J/m^{2}s].
- E_e - the radiation emitted by the snow surface [J/m^{2}s].
- E_s - the sensible heat flux, caused by the temperature difference between the snow surface and in the atmosphere above the snow [J/m^{2}s].
- E_l - the latent heat flux, caused by the difference of vapour pressure at the snow surface and the atmosphere above the snow [J/m^{2}s].
- E_c - the energy brought the snow surface by rainfall [J/m^{2}s].

In the practical cases the changes of energy of snow cover is expressed in terms of meltwater millimeter instead of the energy units.

If there are data available for calculation of the energy terms on the right-hand side of Eq.(1) energy balance method can be applied. In the most practical cases these terms cannot be computed with acceptable accuracy. In these cases temperature index method can be used.

The basic equation of the temperature index method:

E_o-E_z = M = (C_o+ C_p P) (T- T_o)

where:

- M - the quantity of water melted/refreezed during the selected period of time [mm]
- C_o - the temperature index [mmoC^{-1}]
- Cp - coefficient for taking into account the effect of precipitation [^{o}C^{-1}]
- P - the precipitation [mm]
- T - the air temperature [^{o}C]
- T_o - the threshold air temperature [^{o}C]

The temperature index is considered time-variable, as a consequence of seasonal changes of the solar radiation values corresponding to the same air temperature, and even of changes of the albedo of the snow surface.

When the precipitation falls in the form of snow, precipitation observation data are to be corrected as a function of speed of wind, with the following formula:

$P = P_oC$;

$C = 1.0+(u-1.0)S_c$

where:

- P - the corrected value of precipitation [mm]
- Po - the observed value of precipitation [mm]
- C - the calculated correction coefficient
- U - speed of wind [m^3/s]
- S_c - the correction factor

The compression of snowcover is calculated as follows:

$\rho_{h,i} = \rho_{hmax} (1-e^{-k_\Delta t})\rho_{h,i-1}e^{-k_\Delta t}$

where:

- $\rho_{h,i-1}$- the density of snowcover in the (i-1)-th time step [gr/cm^3]
- $\rho_{h,i}$ - the density of snowcover in the i-th time step [gr/cm^3]
- ρ_{hmax} - the obtainable maximum density of snowcover [gr/cm^3]
- Δt - the time step
- k - rate of compression of snowcover

The intensity of the infiltration of effective precipitation into the soil, and thus the time variation of the rate of infiltration, depends basically on the frozen or not frozen state of soil and the depth of soil frost. Consequently a snow model can supply acceptable input to a precipitation-runoff model when it able to provide information if soil frost too.

This process was accounted for in our model with the following expression:

$TF_i = TF_{i-1}TF_{DH} - \alpha_{TF}T_l$

where:

- TF_i - the depth of soil frost in the i-th time step [cm]
- TF_{i-1} - the depth of soil frost in the (i-1)-th time step [cm]
- TF_{DH} - the soil frost reduction coefficient corresponding to snow depth H.
- α_{TF} - the coefficient of soil frost [$cm/^oC$]
- T_l - the mean air temperature [^oC]

<u>Calculation of the energy terms</u>

The short wave radiation can be calculated by the following formula:

$E_{sw}= E(a_{sw} + b_{sw} N_f)$

where:

- E_{sw} - the short wave radiation arriving onto the snow surface [J/m^{2}s]
- E - the maximum possible radiation depending on the geographical altitude and on the season [J/m^{2}s]
- N_f - fraction of the sky covered by clouds expressed as decimal fraction asw, bsw - empirical constants

In case of temporary lack of data, cloudiness is approximated in a function of the daily temperature fluctuation with the following formula:

$Nf = af + b_f (T_{max}-T_{min})$

where T_{max} and T_{min} are the daily maximum and minimum air temperatures, respectively, and a_f , b_f

are empirical constants.

The albedo of the snowcover is mostly affected by the crystalline structure of the snow, which letter is changing in function of the melting process. The crystalline structure of the melting snow will be completely restructured, and this new structure remains unchanged after refreezing.

This process is described as follows:

$A_i = A_o e^{-ka_{\sqrt{\tau}}}$; $\tau = \Sigma T_{max}$

where:

- A - albedo of the snowcover in the i-th time step.
- A_o - the maximal albedo value of newly fallen snow
- τ - the sum of maximum positive temperature values observed since last snowfall [^{o}C].
- ka - empirical constant

Atmospheric radiation is calculated by the Stephan-Bolzmann law in the form of:

$E_{lw} = \varepsilon_a \sigma T_l$

where:

- E_{lw} - the atmospheric radiation [J/m^{2}s]
- ε_a - the radiation coefficient of the atmosphere
- σ - the Stephan-Boltzmann constant (5.735 10^{-8} J/m^{2}K^{2}s^2)
- Tl - the absolute temperature of the emitting object [^{o}K].

Relationship of Brundt for calculation of ε_a:

$\varepsilon_a=(a_{lw}+b_{lw}\, e\,)$

where:

- e - the vapour pressure of the atmosphere [mbar]
- a_{lw},b_{lw}- empirical constants

The value of vapour pressure of the atmosphere can be calculated from the value of dew point. In case of temporary lack of data, dew point can be estimated by the daily minimal air temperature.

Atmospheric radiation becomes more intensive when the sky is cloudy, since clouds also emit radiation. This effect can be taken into account by modifying the radiation coefficient:

$\varepsilon_a = \varepsilon_a (1 + 0.24 N_f)$

To carry out the calculation knowledge of the temperature of the emitting object is also needed. This is given by the following relationship:

$T_l=T_a+0.1(N_f \Delta T)$

where:

- T_l - the temperature of the emitting object (clouds) [^oC].
- T_a - the air temperature [^oC].
- ΔT - the difference between cloud temperature and air temperature [^oC].

Earth radiation can be calculated by the Stephan-Bolzmann law too. The temperature of the snow surface can be considered as that of the air temperature during the day, and the dew point during the night.

The sensible heat flux is usually calculated with the following expression:

$E_s = D_{su} (T_h-T_o)$

where:

- E_e - the sensible heat flux [J/m^2s]
- D_s - the coefficient of energy exchange [$J/m^{2o}C$]
- u - the speed of wind at h m above the snow surface [m/s]
- T_h - the air temperature at h m above the snow surface [^oC]
- T_o - the temperature of the snow surface [^oC]

The latent heat flux is described as:

$El = D_{lu} (e_h-e_o)$

where:

- E_l - the latent heat flux [J/m^2s]
- D_l - the coefficient of energy exchange [$J/m^{2o}C$]
- u - the speed of wind at h m above the snow surface [m/s]
- e_h - the atmospheric vapor pressure at h meter above snow surface [mbar]
- e_o - the vapor pressure of the atmosphere at the snow surface [mbar]

The energy provided by rainfall it described as:

$E_c = 4210\ T_p P$

where:

- E_c - the energy input via rainfall into the snowcover [J/m^2s]
- T_p - the temperature of rain [^oC]
- P - the rainfall intensity [mm/s]

The temperature of rain can be approximated by that of the air.

The problem of model structure identification and model parameter estimation is clearly still unresolved as it is declared in a similar study (Clark et al., 2009): Lack of data for model evaluation is a ubiquitous problem in hydrology, and there is increasing recognition of the need to compare model output to multiple quantitative and qualitative data sources (e.g., Gupta et al., 1998). Indeed, there is an emerging research trend to creatively use all available data in such a way that the data provides information on both the behaviour of model sub-components and appropriate values for individual model parameters.

For example, qualitative information on snow duration across the Alpine-Carpathian region can provide more information on appropriate values of melt parameters than quantitative data on snow water equivalent at a single station location. Further efforts in improving snow models, that is, diagnosing and correcting model weaknesses or regionalizing model parameter sets, will require creative assessment of a much broader set of information than the statistics on seasonal snow climatology considered in this paper. Important data sources for future studies will be both satellite data on snowcovered area.

The use of snow covered area

Among the objectives of the studies, the possible usage of satellite information for snow water equivalent calculation was included. Temporal evaluation of snow cover over large areas can be successfully observed using different satellite images.

The quality of the snow related processes calculation (like snow accumulation, snow melting) might be improved by application of satellite images. However, after a detailed investigation, it becomes obvious that the development of a universally applied correction method based on satellite information meets serious difficulties. The main sources of uncertainties are:

- satellite information is available only for cloud free areas;
- satellite information provide data on snow coverage only without any information on the quantity of snow water equivalent.

Theoretically the accuracy of snow simulations can be improved by optimally combining model output with observations. This can be done by assimilating point snow water equivalent observations and satellite-derived estimates of snow-covered area into the model (Clark et al., 2009; Slater & Clark, 2006). Data assimilation will provide snow information that takes advantage of the relative strengths of data and models, and the merged data-model product will be of greater accuracy than either the data or model alone. However, data assimilation will only improve presentday simulations, and there is a need to identify appropriate parameter sets that can be used for future scenarios, for example, to simulate the impact of climate change on water resources.

Relative to the Danube Basin a very relevant study was carried out by Parajka and Blöschl (2006) to evaluate the Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover product over the territory of Austria. The aims of the referred study were (a) to analyse the spatial and temporal variability of the MODIS snow product classes, (b) to examine the accuracy of the MODIS snow product against in situ snow depth data, and (c) to identify the main factors that may influence the MODIS classification accuracy. The authors used daily MODIS grid maps (version 4) and daily snow depth measurements at a dense network of climate stations. The results indicated that, on average, clouds obscured 63% of Austria, which significantly restricted the applicability of the MODIS snow cover images to hydrological modelling. It was also noted that on cloud-free days, however, the classification accuracy is very good with an average of 95%. There is no consistent relationship between the classification errors and dominant land cover type and local topographical variability but there are clear seasonal patterns to the errors. In December and January the errors are around 15% while in warm months less than 1%. This seasonal pattern is related to the overall percentage of snow cover, although in spring, when there is a well-developed snow pack, errors tend to be smaller than they are in early winter for the same overall percentage of snow cover. Overestimation and underestimation errors balance during most of the year which indicates little bias. The comparison made in the Austrian study of daily air temperature maps with MODIS snow cover images indicated that almost all MODIS overestimation errors are caused by the misclassification of cirrus clouds as snow.

Even though the MODIS snow product analysed was based on a liberal cloud mask and an improved cloud detection algorithm (Riggs & Hall, 2002), the average cloud cover is 63%. This is very likely due to the climate conditions over the Alps rather than an artefact of the algorithm (Parajka & Blöschl, 2006; Parajka et al., 2012). This large cloud cover percentage has significant implication for the application of the MODIS snow product.

Overall, the inaccuracy of the method for snow water equivalent calculation using the satellite information can be unacceptably high.

Assessment of snow resources

Among the objectives of the studies, the presentation of snow depths and snow water equivalent calculation was included (Figure 1.27). Temporal evaluation of snow cover over medium and large sub-basins is also followed on the graphs (Figure 1.28).

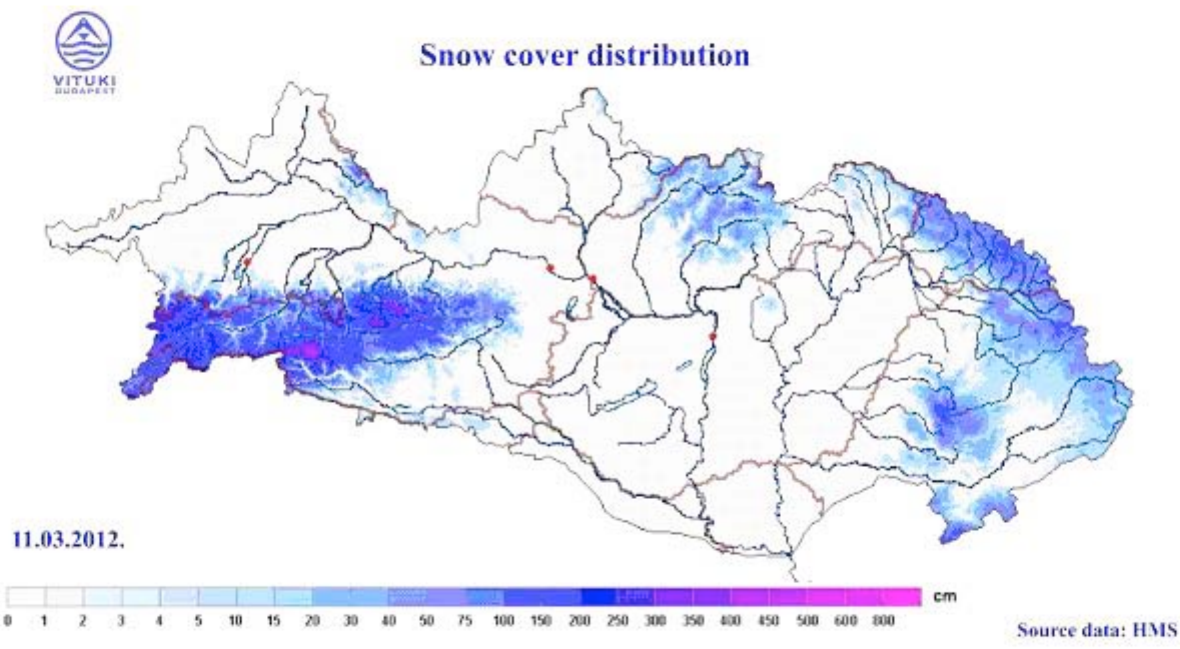

Figure 1.27. Snow depths in the Upper –Central Danube region (early March 2012)

The overall seasonal pattern shows that the maximum of snow resources usually is reached in the Carpathian - Dinarid regions at the end of February till mid-March. The Alpine part of Danube Basin is characterised by the maximum of overall snow resources in mid-March to early April.

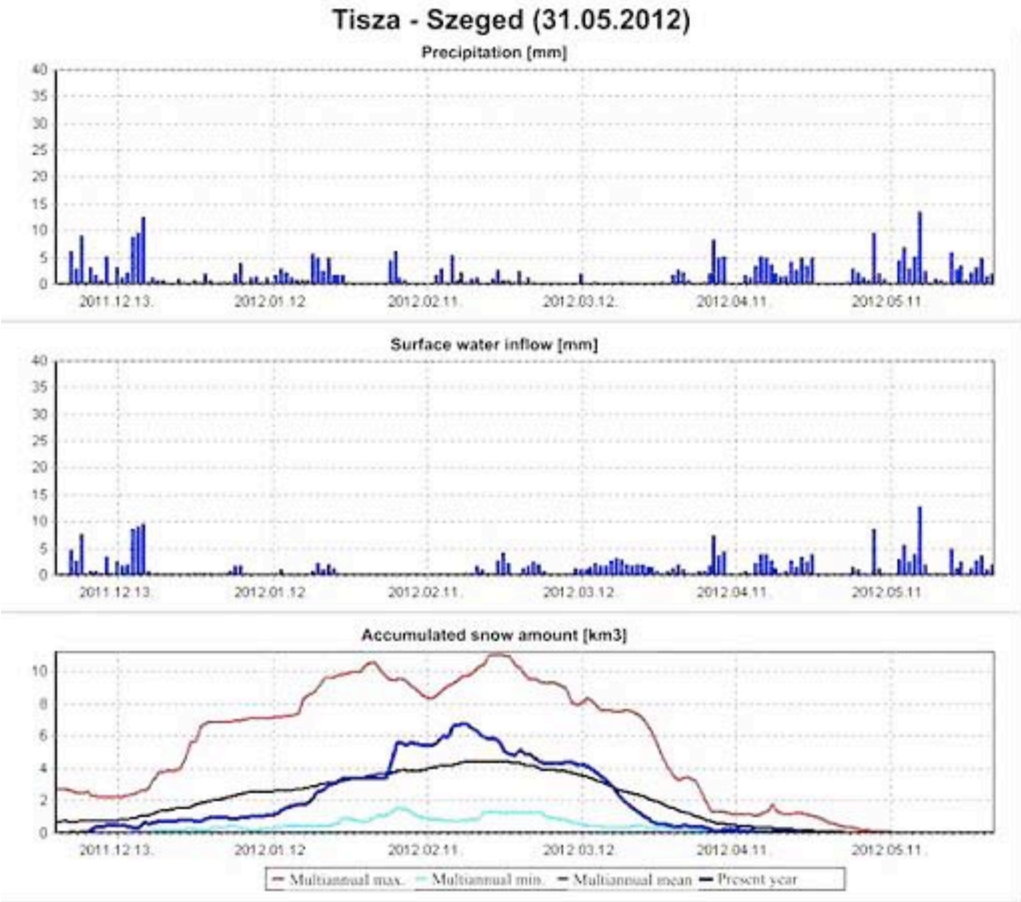

Figure 1.28. Water budget of the snow pack, Tisza – Szeged, 2011-2012.

<u>Early warning of spring floods</u>

Although floods can come at any time, the possibility of flood formation is higher during late winter and early spring when snow is present, the groundfloor is frozen and deciduous forests have no leafs Ice phenomena sometimes make the situation even more dangerous when ice jams result extensive inundations even at relatively moderate flow rates when the return period of the flood peak (in terms of discharges) is short. Rain on snow events are the most dangerous hydrological events at many sub-basins of the Danube Basin.

Accurate estimation of the volume of water stored in the snow pack and its rate of release is essential to predict the flow during the long snowmelt period. Owing to the distinct elevation distribution of the watersheds the snowmelt affected period is long while different parts of the mountain ranges produce snowmelt induced runoff. An important variable in the mountainous watersheds during the snowmelt season is the aerial extent of the snow cover. The water equivalent in the snow pack over the large area is the main factor defining the volume of runoff during spring months. Snow accumulation and ablation processes may go on in certain elevation zones and in the same time rainfall induced component becomes more significant as air temperature rise consumes snow resources at lower elevations.

The overall seasonal pattern shows that the maximum of snow resources usually is reached in the Carpathian - Dinaride regions at the end of February till mid-March. The Alpine part of Danube Basin is characterised by the maximum of overall snow resources in mid-March to early April. The snow resources are only the first prerequisite to predict expected seasonal runoff and flood peaks and together with those to indicate the danger of possible flooding.

Simple linear regression type of relationships were designed to calculate monthly runoff and monthly maximum water levels as function of the snow resources, and anomalies of monthly volumes of precipitation (rainfall and snow) and that of air temperatures. As far as there are no reliable long term forecasts of precipitation and air temperature available climatic means can be taken into consideration with the indication of standard deviations producing lower and higher estimates.

Application of the described scheme using March 1st estimates of snow resources produced long term predictions of the monthly flow volume for Danube-Budapest and Tisza-Szeged (Figure 1.29 and Figure 1.30) for the last two decades. Instead of the climatic values derived from seasonal predictions of precipitation and air temperature, data from the Hungarian Meteorological Service were used.

Spring time runoff largely depends on the snowmelt component and it gives a possibility to estimate expected seasonal volume of flow and flood peaks. Seasonal forecasts based on the relationship between snow resources and expected precipitation during spring months have been analysed for Danube and Tisza rivers.

Figure 1.29. Predicted and observed monthly runoff Danube Budapest.

On the Danube at Budapest low March estimates of monthly runoff were more or less followed by low observed values during most of the 1990's. The expected higher values for the years 2006- 2010 were not proved by observations and the flow passing Budapest cross section remained around or even below the lower estimates. April values were underestimated in the 1990s' but higher values captured after 2006. Higher May volumes of observed runoff remained within the predicted range during the 1990s' but predictions mostly failed after 2006 (Figure 1.29).

Tisza-Szeged monthly runoff predictions were relatively successful in March, most of the estimates remained within the predicted range, however the high value of 2001 was not captured. Less skill was proved for April while May is a complete failure with almost all of the observed values are outside the predicted range (Figure 1.30).

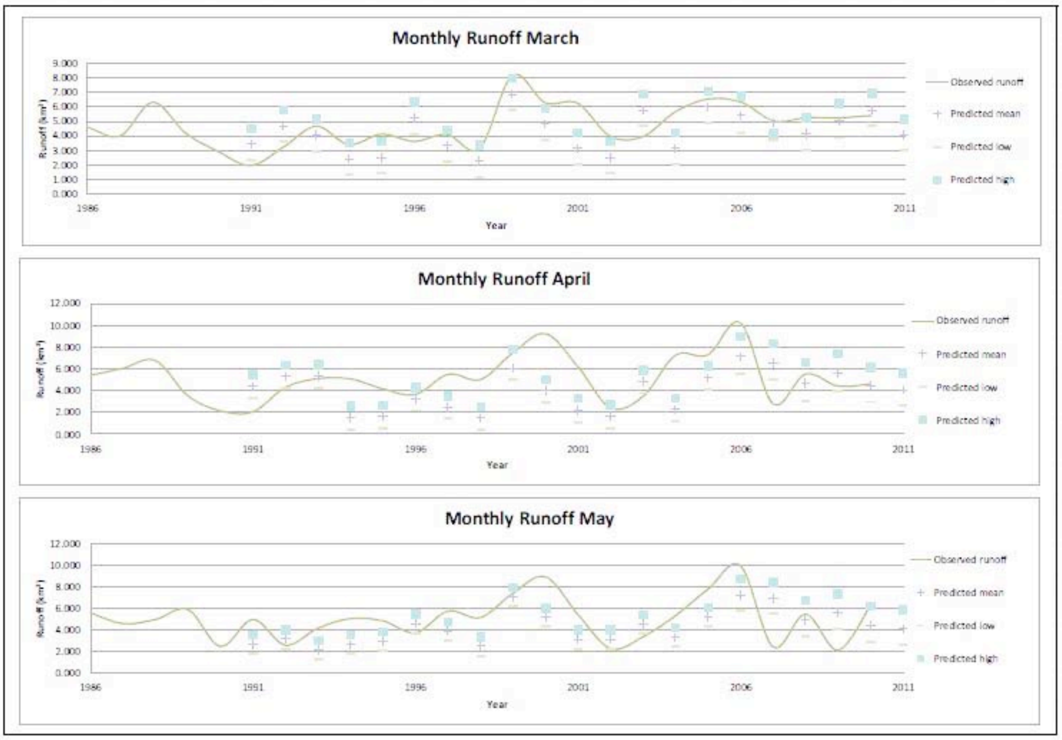

Figure 1.30. Predicted and observed monthly runoff Tisza – Szeged.

The relation between spring time runoff, monthly values and the peak flow were utilised to have estimates of monthly maximum water levels at the two key stations on the Danube and Tisza. Observed and predicted values are shown on Figure 1.29 and Figure 1.30.

Danube - Budapest low March estimates of monthly runoff for the 1990's were followed by low peaks and it coincides more or less with the observations. In a similar manner the expected higher values for the years 2006-2010 were not proved by observations. March predictions were completely unsuccessful for the years 1998-2002, when observed highs were significantly larger than those within the predicted ranges. Even less skill was proved for April and May even worse (Figure 1.29).

Comparison of predicted and observed monthly maximum water levels and flood crests indicated very large scatter (Figure 1.33). March estimates for the Tisza River at Szeged give some positive results. Little sign of that can be seen for April at the same station. Danube predictions fail in most cases together with the May attempts for the Tisza.

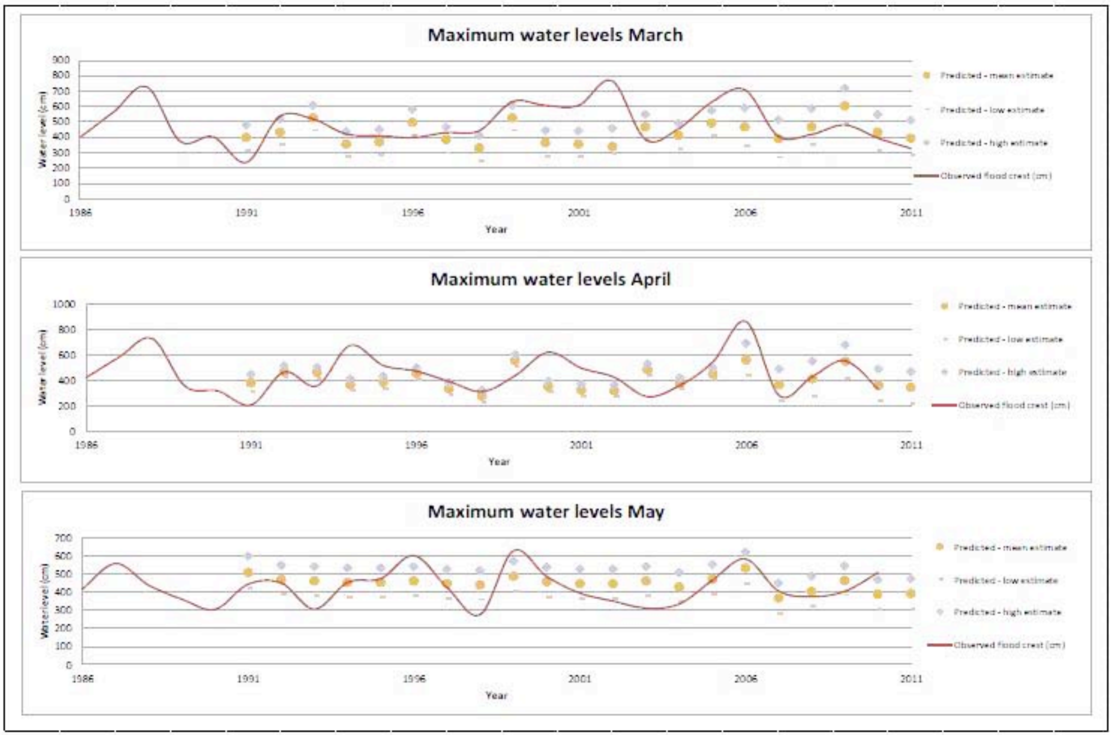

Figure 1.31. Predicted and observed monthly maximum water levels Danube Budapest.

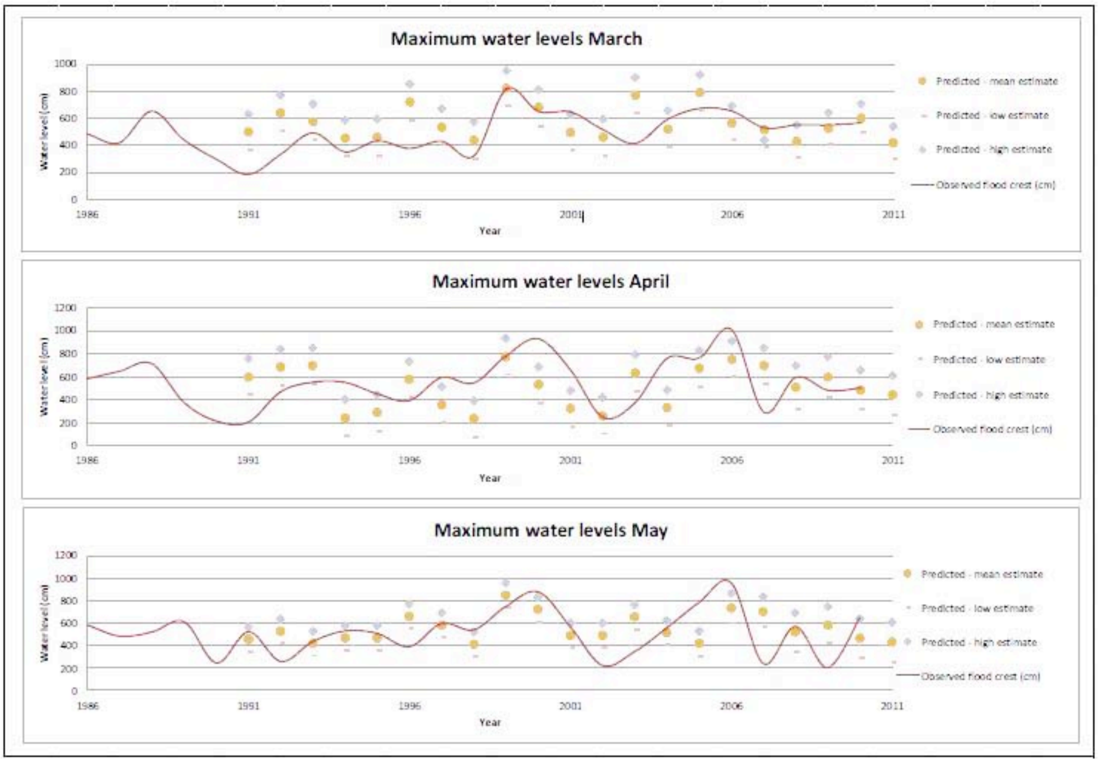

Figure 1.32. Predicted and observed monthly maximum water levels Tisza – Szeged.

The results received call for the importance of meteorological predictions. In most cases intensive rainfall on snow events trigger high floods which are not captured by monthly values. The now resources base prediction of the spring flow has limited value for flood early warning purposes. Slow and continuous snow melt may consume extreme snow resources while water levels remain the critical stages and no inundation occurs.

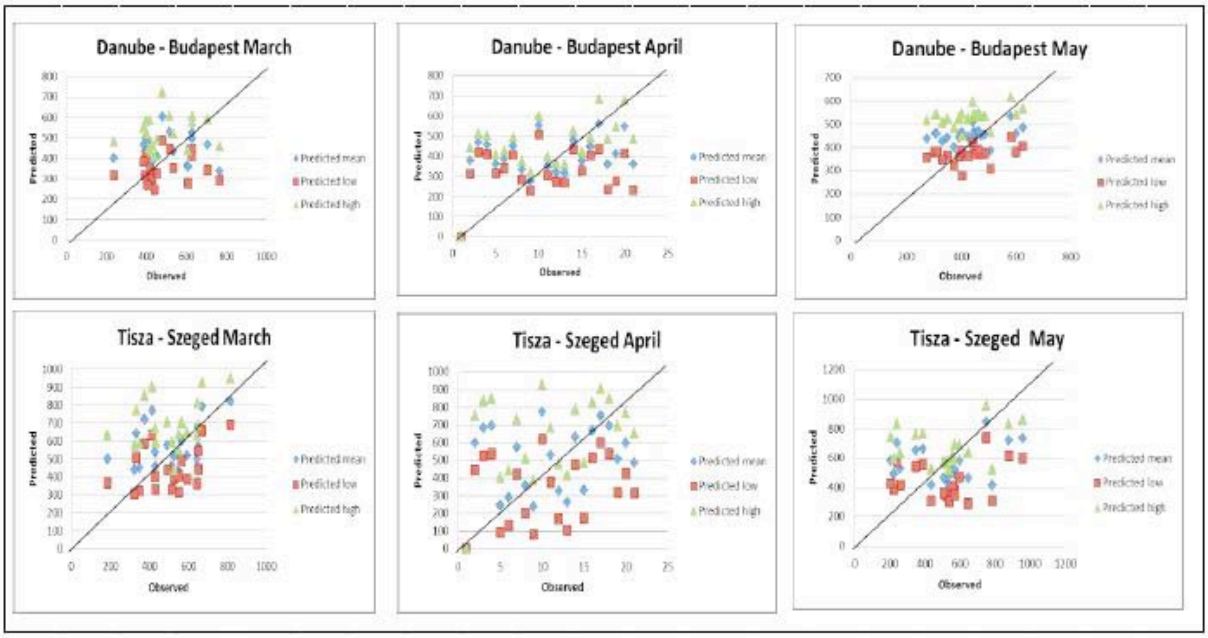

Figure 1.33. Comparison of predicted and observed monthly maximum water levels.

<u>Conclusions</u>

The HOLV snowmelt model is developed by the Hungarian National Hydrological Forecasting Service (VITUKI OVSZ/NHFS) proved to be an easily applicable tool to estimate regional snow resources for the Danube Basin. The distributed newly developed version covers over a grid with 0.1 degree resolution is in use to assess snow accumulation and ablation. The snowmelt model has a flexible structure; it is able to change its own structure in function of data availability.

The quality of the snow related processes calculation (like snow accumulation, snow melting) might be improved by application of satellite images. However, after a detailed investigation, it becomes obvious that the development of a universally applied correction method based on satellite information meets serious difficulties.

Seasonal forecasts based on the relationship between early spring snow resources and expected precipitation during spring months have been analysed for the Danube and Tisza rivers. Comparison of predicted and observed monthly maximum water levels and flood crests indicated very large scatter. March estimates for the Tisza River at Szeged give some positive results. Little sign of that can be seen for April at the same station. Danube predictions fail in most cases together with the May attempts for the Tisza. The results received call for the importance of meteorological predictions. In most cases intensive rainfall on snow events trigger high floods which are not captured by monthly values. The now resources base prediction of the spring flow has limited value for flood early warning purposes. Slow and continuous snow melt may consume extreme snow resources while water levels remain the critical stages and no inundation occurs.

The rapid development of medium range meteorological forecasting and especially the application of ensemble forecasts give hope to design a complete chain of advisory, seasonal prediction, early warning, medium range and short time forecasting of floods during periods when the snowmelt component contribution is high. Snow resources based scenario simulations can also be useful to find ‘worst case’ scenarios and possible to operate flood regulation reservoirs or other water supply reservoirs with designated flood reduction storage volumes.

1.4. Recommendations for harmonisation and development of an Early Warning System in the Danube region

It is the aim of this section to propose a flood risk management strategy for the Danube region, and it is proposed that this is done in line with the EU flood Directive.

Within the EU flood Directive, Flood Risk Management Plans coordinated at the level of River Basins must be produced for all areas that have been identified as being at potential significant risk of flooding. The Flood Risk Management Plans must establish appropriate objectives for the management of flood risks within these areas. These plans will aim to reduce the potential adverse consequences of flooding on human health, the environment, cultural heritage and economic activity.

1.4.1. EU-flood directive

The Directive 2007/60/EC on the assessment and management of flood risks entered into force on 26 November 2007.

The Directive was proposed by the European Commission on 18/01/2006, and was finally published in the Official Journal on 6 November 2007. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The Directive requires Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU.

The Directive shall be carried out in coordination with the Water Framework Directive, notably by flood risk management plans and river basin management plans being coordinated, and through coordination of the public participation procedures in the preparation of these plans. All assessments, maps and plans prepared shall be made available to the public.

Member States shall furthermore coordinate their flood risk management practices in shared river basins, including with third counties, and shall in solidarity not undertake measures that would increase the flood risk in neighboring countries. Member States shall take into consideration long term developments, including climate change, as well as sustainable land use practices in the flood risk management cycle addressed in this Directive.

Preliminary flood risk assessment

Based on information available or readily derivable, the assessment will include:

- Development of river basin district maps
- Description of historical flood events, for which significant adverse impacts have been observed or are likely to be encountered in the future
- Assessment of the potential adverse consequences of floods taking into account future land use and impacts of climate change on the occurrence of floods.

Flood hazard and flood risk mapping

In general, two sets of maps are required:

- Flood hazard maps defining geographic areas likely to be flooded with low, medium and high probability
- Flood risk maps presenting the potential adverse impacts associated with the above scenarios.

Flood risk management plans

Based on appropriate management objectives for flood risk, the management plans shall include:

- Cost benefit analysis
- Flood risk zoning
- Prevention, protection and preparedness initiatives
- Recommendation for sustainable land use practice and flood control measures
- The plans shall be made available to the public.

1.4.2. A flood risk management strategy for the Danube region

Some points that should be taken into account while developing a flood risk management plan for the Danube region could include: the analysis of the basin, a thorough flood risk assessment, and a strategy for public participation, institutional changes and financial mechanisms.

1.4.2.1. Reducing flood risks via natural retention

A strategy to mitigate floods in an ecological manner should be based on improving river basin land-use, preventing rapid runoff both in rural and urban areas, and improving a trans-national effort to restore rivers' floodplains

- When planning the reactivation of protected floodplains, special attention should be paid to avoiding possible negative effects on agriculture, rural settlements and water pollution from contamination due to intensive use of chemicals on agricultural lands.
- The appropriate strategy consists of three steps: retaining, storing and draining; therefore protection and restoration of infiltration areas in the upper parts of the catchment and conservation and restoration of wetlands are crucial for the water retention
- The storage effect of vegetation, soil, ground and wetlands has an important mitigating effect particularly in minor or medium-scale floods. Each of these storage media is capable of retaining certain quantities of water for a certain length of time.

1.4.2.2. The improvement of flood forecasting and early flood warning systems

Flood forecasting is an important component of flood warning, where the distinction between the two is that the outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations, while "flood warning" is the task of making use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted. Further activities around flood forecasting should be organised:

1. Improve flood forecasting and warning suited to local and regional needs as necessary
2. Increase the capacity building and level of preparedness of the organizations responsible for flood mitigation
    - Support for the preparation of, and coordination between, subbasin-wide flood action plans
    - Creating forums for the exchange of expert knowledge
    - A recommendation for a common approach for the assessment of flood-prone areas and the evaluation of flood risk

1.4.2.3. The interlinking of national and/or regional systems

Floods do not respect boundaries, be they national, regional or institutional. Therefore, trans-boundary flood risk management is imperative – it involves both governments – as borders are involved – and their people – as risk is involved. Transboundary cooperation on flood risk management is not only necessary, but also beneficial. Early warning by upstream countries can save lives and reduce economic losses. Moreover, cooperation helps to strengthen the knowledge and information base and enlarge the set of available strategies. Widening the geographical area considered in basin planning enables finding better and more cost-effective solutions. Finally, disaster management is highly dependent on early information and requires data and forecasts from the whole river basin.

Points to consider:

1. joint monitoring, forecasting and early warning
2. coordinated risk assessment
3. joint planning of measures
4. appropriate legal and institutional frameworks

PREVIEW was a project, funded by the European Union under the FP6 program, that aim to develop at the European scale new or enhanced information services for risk management in support of Civil Protection Units and local or regional authorities, making the best use of the most advanced research and technology outcomes in Earth Observation. Services will be validated under pre-operational conditions.

The risks may result from the direct impact of atmospheric events, from their hydrological consequences or from geophysical events and in some cases be worsened or directly caused by industrial activities. The challenging issue is to enhance risk mitigation through better prevention, better anticipation and more accurate assessment at various time and spatial scales of situations at risk, improved timely dissemination of meaningful and adapted early warning information, fitted to the societal needs and to the operations of rescue forces. This has to be done in a joint effort of all actors and citizens to develop risk awareness and culture.

The main axe of development through PREVIEW is: Improvement of the services contents: quality and harmonization of the information services supporting the decision making at the operational level, improving information collection, aggregation and intelligence methodologies, developing synergies, cooperative work and inter-operability capacities among operators for a widespread application of the best solutions at national, regional, and European scale.

It is important to know, make use and contribute to initiatives like this that foster harmonization and integration of data at regional scale.

1.4.2.4. Creation of scenario's to take into account climate change

It is essential that the impacts of climate change are incorporated into water resource plans and flood risk assessments now as its effects are already being felt. Although individual events cannot be attributed solely to climate change, extremes of recent years can be expected to occur more frequently in future.

1. inventory of catchment wide impacts of climate change scenarios on different sectors of importance
2. flood risk management must be sustainable and should adopt an adaptive or, where appropriate, an assumptive approach with respect to such impacts and investigate optimum flood risk intervention strategies taking into account the possible effects of climate change

1.4.3. Components of a flood management plan.

Some of the components that need to be included in a flood management plan for the Danube region could include:

1. Basin Flood Management Policy
   - 1.1 National flood management policy
   - 1.2 Basin flood management vision
     - Future plan of socio economic development in the basin
     - Basin flood management policy
   - 1.3 Legal and institutional setup
     - Role and responsibility of organizations at each level (Institutional set up for flood emergency management, community based organization)
     - Available economic mechanisms
     - Environmental issues
     - Public participation
2. Outline of the basin
   - 2.1 The outline of natural condition
   - Geological, Meteorological, Hydrological, Geomorphologic and Environmental
   - 2.2 Administrative setup
     - Role and responsibility of existing institutions in the basin
   - 2.3 The outline of socio economic activities in the basin
     - Demographic conditions, Land use pattern, Livelihood sources and Asset distribution
   - 2.4 Beneficial aspects of floods
   - 2.5 Negative socio economic impacts of floods
     - Socio economic damage caused by past flooding

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Part 2: Case Studies for Invasive Aquatic Species

(Vadim Panov, Boris Alexandrov, Mikhail Son, Vitaly Semenchenko, Momir Paunovic, Frances Lucy, Alexander Prokin, Natalia Pulenko, Vitaly Semenchenko, Vladimir Shestakov)

Abstract

Human-mediated introductions of invasive alien species (IAS) is an increasing environmental pressure for the Black Sea region, which needs to be properly estimated in order to define and implement relevant management actions at the regional and national levels. In order to address IAS-related issues and contribute to relevant capacity-building on the regional level, with support of EnviroGRIDS project we collected relevant information on aquatic IAS in four selected assessment units in the Black Sea catchment area, which was deposited in the Regional Euro-Asian Biological Invasions Centre (REABIC) information system. The selected assessment units (case studies) included the Black Sea itself, and river basins of three main tributaries to the Black Sea - Danube, Dnieper and Don rivers. The collected information was further used for estimation of IAS-related environmental indicators, most useful for early warning purposes. Specifically, our analysis of collected information on historical records of aquatic alien species indicated substantial increase of rates of new species introductions during the last two decades in the Black Sea and its main tributaries. Increasing shipping activities, canals and aquaculture in the Black Sea and its basin during last decades are considered as main reasons of this drastic increase. In case no relevant management options will be implemented, new introductions of IAS are expected together with the associated negative ecological and socio-economic consequences. In addition to reporting of selected IAS-related environmental indicators for our case studies, we provided a description of the current early warning services of the Regional Euro-Asian Biological Invasions Centre information system along with recommendations for development of operational regional early warning system on IAS, specifically, to consider the incorporation of Open Access journals in information systems on IAS as innovative approach to IAS-related information management.

2.1. Introduction

Invasive alien species (IAS) are plants, animals, fungi and microorganisms whose introduction and/or spread outside their natural past or present ranges pose a risk to biodiversity or have other unforeseen negative consequences. IAS have been recognised as the second most important threat to biodiversity at the global level (after direct habitat loss or destruction) (CBD, 2001; MA, 2005). They also represent a serious impediment to conservation and the sustainable use of biodiversity, and have significant adverse impacts on the goods and services provided by ecosystems, both globally and in the European Union (EU) (EEA, 2012). Furthermore it also poses a serious risk for human health (for instance, release of human pathogens like *Vibrio cholerae* within ballast waters of ships).

Recognizing the need for robust action to control biological invasions and thus mitigate their impacts on biodiversity, ecosystem services and human activities, the European Commission issued a Communication presenting policy options for an EU Strategy on Invasive Species four years ago (EC, 2008). This communication highlighted the magnitude of the impacts of biological invasions in Europe and the urgent need to take action. The EU Biodiversity Strategy (EC, 2011) stresses the need to combat invasive alien species (IAS) through its Target 5: "By 2020, IAS and their pathways are identified and prioritized, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS". Currently, a dedicated legislative instrument is being developed by the Commission (to be launched in 2013) as dictated by Action 16 of the Biodiversity Strategy. European countries and their relevant institutions have or will have, under the developing EU legislative instrument, obligations and commitments under both the European and global frameworks in respect to IAS. These include prioritising pathways for prevention, identifying the most harmful species for responses, enforcing effective early warning and rapid response mechanisms, developing indicators of trends and responses, and other management strategies (Katsanevakis et al., 2013).

Human-mediated introductions of IAS is an increasing environmental pressure for the Black Sea region, which needs to be properly estimated and relevant management actions should be implemented at the regional and national levels. On the regional level, the issue of IAS introductions has been also recognized and addressed in relevant regional agreements (see review in EnviroGRIDS Deliverable 5.11).

Essential scientific information on IAS and relevant expertise are available in the region, but this information remains generally unpublished (or published with serious delays) and international networking in information management in the region is generally lacking. This is one of reasons for the absence of effective management of invasive species in the region.

In order to address these issues and contribute to relevant capacity-building on the regional level, within EnviroGRIDS project we collected relevant information on aquatic and terrestrial invasions in the Black Sea catchment area. This information is stored in relevant databases, including those hosted by the The Regional Euro-Asian Biological Invasions Centre (see in section 2.4), and conducted analysis of relevant environmental indicators, useful for early warning purposes, which is present in this report. Other results of these activities, including the developing risk assessment based Decision Support System (DSS) for management of introductions of invasive alien species for the Black Sea basin are present in the related project deliverable EnviroGRIDS_D5.4.

2.2. Indicators on Aquatic Invasive Species for Early Warning

The Black Sea catchment area is linked with other parts of Europe via complex network of navigable inland waterways, with main river basins (Danube, Dnieper and Don basins) serving as important southern parts of European inland invasion corridors (Panov et al., 2009; 2010; Figure 2.1). The current invasion corridors and the projected future developments of the European network of inland waterways may highly facilitate the transfer of aquatic IAS across European inland waters and coastal ecosystems. Appropriate risk assessment-based management options are required to address risks posed by human-mediated introductions of these species (Panov et al., 2009). Also, there is an urgent need for open information on IAS in the Ponto-Caspian area (Panov, 2004), and, specifically, for relevant Decision Support System for the Black Sea area with early warning functions (Panov et al., 2012).

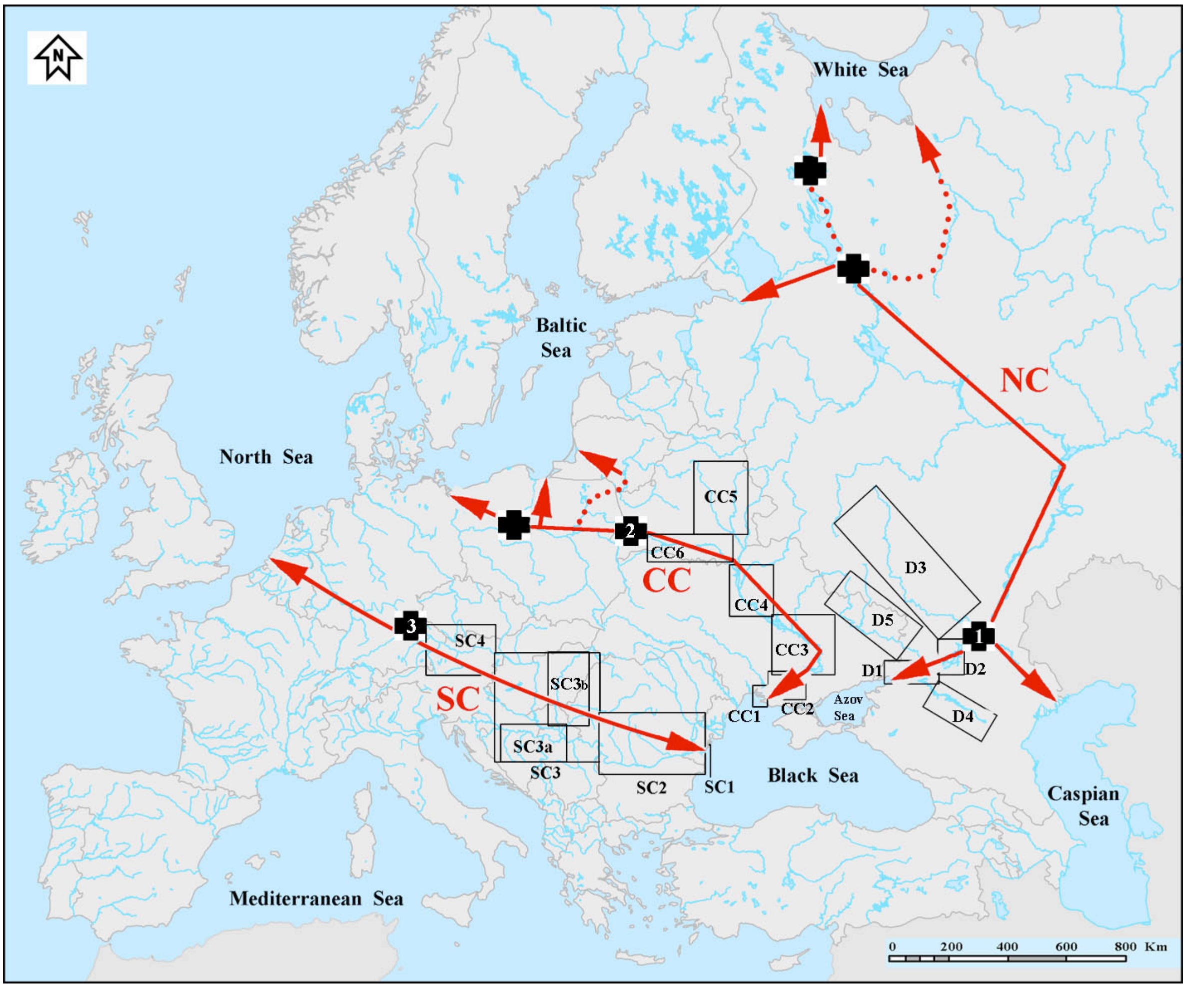

Figure 2.1. Main invasion corridors in Europe, related to the Black Sea catchment area: NC – Northern invasion corridor, CC – Central invasion corridor, SC – Southern invasion corridor (after Panov et al., 2009, modified). Black crosses indicate main canals: 1 Volga-Don Canal, 2 Bug-Pripyat Canal, 3 Ludwig Canal and Main-Danube Canal. Boxes indicate Assessment Units within main river basins. Assessments units within the Don River basin: D1 – Lower Don River, D2 - Tsymlyansk Reservoir, D3 - Upper and Middle Don River basin, D4 – Manych River basin, D5 - Severskii Donets River basin. Assessments units within the Dnieper River basin: CC1 - Dnieper-Bug Liman, CC2 – River Dnieper Delta and Kahovka Reservoir, CC3 – Zaporozhje, Dneprodzerzhinsk and Kremenchug reservoirs, CC4 - Kanev and Kiev Reservoir, CC5 – upper Dniepr River, CC6 – Pripyat River. Assessments units within Danube River basin: SC1 – River Danube Delta, SC2 - lower part of River Danube, SC3 - middle part of River Danube, SC3a - River Sava, SC3b – River Tisa, SC4 – upper part of River Danube).

As part of EnviroGRIDS project activities, we developed database on alien species records in the Black Sea catchment area, based on analysis of published data and results of our own field studied. Information stored in this database was further used for estimation of relevant IAS-related environmental indicators for main assessment units within the Black Sea catchment area, including Black Sea itself, and river basins of three main tributaries to the Black Sea, Danube, Dnieper and Don rivers (Figure 2.1). The European Environmental Agency (EEA) 'Typology of indicators' and the Driving forces–Pressures–State–Impact–Response (DPSIR) framework were used to structure estimated environmental indicators in the socio-economic context (Panov et al., 2009; 2012). Detailed description of these indicators is provided in the project deliverable EnviroGRIDS_D5.10. In this Deliverable we focused on assessment and reporting of most important indicators, useful for early warning purposes.

Targeted indicators on invasive species for early warning included:

1. Indicators for "Pressures"**-** *Biological Contamination Rate* (BCR) and *Trends of alien species invasions*

   The *Biological Contamination Rate* (BCR) of the ecosystem or any Assessment Unit can be estimated as a number of recorded alien species in the Assessment Unit per reporting period (e.g. total number of recorded alien species per 10 years).

   Trends of alien species invasions are indicated by long-term changes in cumulative numbers of new records of alien species in the AU and recognized as useful IAS-related environmental indicator for Europe (EEA 2012). Trends of alien species invasions were estimated for non-native fish and invertebrates for the Black Sea, and basins of main three tributaries to the Black Sea – Danube, Dnieper and Don rivers.

2. Indicators for "State" **–** new records on invasive species and Site-specific Biological Contamination (SBC) index

   The *Site-specific Biological Contamination* (SBC) index has been elaborated to assess biological contamination of the specific sampling site within the Assessment Unit with respect to "richness" and "abundance" contamination (see also Panov et al., 2009).

   The SBC index can be used for assessment of ecological status of the specific location in a water body in respect of contamination by alien species. In accordance to proportion of alien taxonomic orders in the community (ordinal richness contamination) and the relative abundance of alien individuals in the community (abundance contamination), the ecological status of specific location in the Assessment Unit may decline from "High status" (SBC index = 0, alien species absent), to "Bad status" (SBC index = 4, ordinal richness contamination and/or abundance contamination are higher than 50%) (Table 2.1). As examples of assessment of SBC index for macrozoobenthic communities (and corresponding estimations of ecological quality), we conducted special biological surveys in the upper Dnieper River basin (Semenchenko et al., 2013) and in the Lower Don River (Prokin et al., 2013).

3. Indicators for "Impacts" include Black lists of alien species. The *Black List* of alien species for the Assessment Unit includes all invasive species, i.e., all alien species that have high potential to cause ecological impacts and/or high potential to cause negative socio-economic impacts.

Management measures for the DPSIR "Pressures" may include preventive actions toward management of pathways responsible for invasive species introductions. Biological Contamination Rate (BCR) and Pathway-specific Biological Contamination Rate (PBCR) can be used as indicators of the effectiveness of preventive management.

Site-specific Biological Contamination (SBC) index can be recommended as cost-effective 'Quality Elements' (QEs) according to the Common Implementation Strategy of the Water Framework Directive for assessment of ecological status of aquatic ecosystems.

Trends of alien species invasions is an useful indicator both for assessment of the ecosystem state in regard of IAS introductions, and as indicator of the effectiveness of preventive management options.

Table 2.1. Assessment of site-specific biocontamination index (SBCI) based on abundance contamination index (ACI) and ordinal richness contamination index (RCI). SBCI and IBCI classes: 1 (no bio-contamination, “high” ecological status, blue cell), 2 (low biocontamination, “good” ecological status, green cell), 3 (moderate biocontamination, “moderate” ecological status, yellow cells), 4 (high biocontamination, “poor” ecological status, orange cells), 5 (severe biocontamination, “bad” ecological status, red cells) (Semenchenko et al., 2013).

	ACI, %				
RCI, %	0	>0-10	>10-20	>20-50	>50
0	1				
>0-10		2	3	4	5
>10-20		3	3	4	5
>20-50		4	4	4	5
>50		5	5	5	5

Management actions for “State” and “Impacts” may involve the control and eradication of established species from the Black List (according to CBD provisions), and in this regard information of new records of invasive species, primarily published in project supported Open Access journal BioInvasions Records and reported via online early warning module of the DSS (see in section 2.4 of this report) can be used for timely eradication efforts.

2.3. Illustrated Case Studies on Aquatic Invasive Species

In this report we included four case studies on aquatic invasive species – for the Black Sea (Ukrainian coastal waters), and for three main river basins in the Black Sea catchment area, Danube, Dnieper and Don rivers. In this case studies we are reporting results of our assessment of main indicators of alien species, essential for decision making, for these four main assessment units. This information represents a summary of our data, gathered for specific subunits selected within these large areas (Figure 2.1). Technical issues of transferring this information on the level of decision-making are discussed in section 2.4 of this report.

2.3.1. The Black Sea case study (Ukrainian coastal waters)

The Black Sea is particularly heavily affected by non-native species invasions. During last decade, a number of recorded alien species in the sea is rapidly increasing: the list of alien species released in the 2007 in Transboundary Diagnostic Analysis by Black Sea Commission averaged 217 alien species (TDA, 2007), by May 2010 this list included already 254 species (Aleksandrov, 2010), and in the next 2 years total number of registered alien species in the sea reached 265 species, with maximum number of alien species (173) recorded in Ukrainian waters (Aleksandrov et al., 2013).

Our analysis of collected information on records of aquatic alien species indicated, that during last two decades rates of new species introductions in Ukrainian waters of the sea increased substantially: biological contamination rates during last decade doubled (Figure 2.2). Number of new records of alien species for 2001-2012 in Ukrainian waters of the sea averaged for this period 24 new introductions of invertebrate species and 8 new non-native fish introductions, compare to 11 and 8 introductions during the previous decade (Figure 2.2).

Increasing shipping activities in the sea during last 2-3 decades are considered as one of main reasons of this drastic increase in new introductions, primarily associated with release of ballast waters. In case if no relevant management options implemented, by 2020 more than 80 new alien species can invade the Black Sea ecosystem (Aleksandrov, 2010). However, at this stage coastal countries are not implementing yet relevant management options, recommended by the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM, 2004). This Convention is not yet into force, and at this stage, among Black Sea countries, only Russian Federation amended the accession of Convention on 24 May 2012.

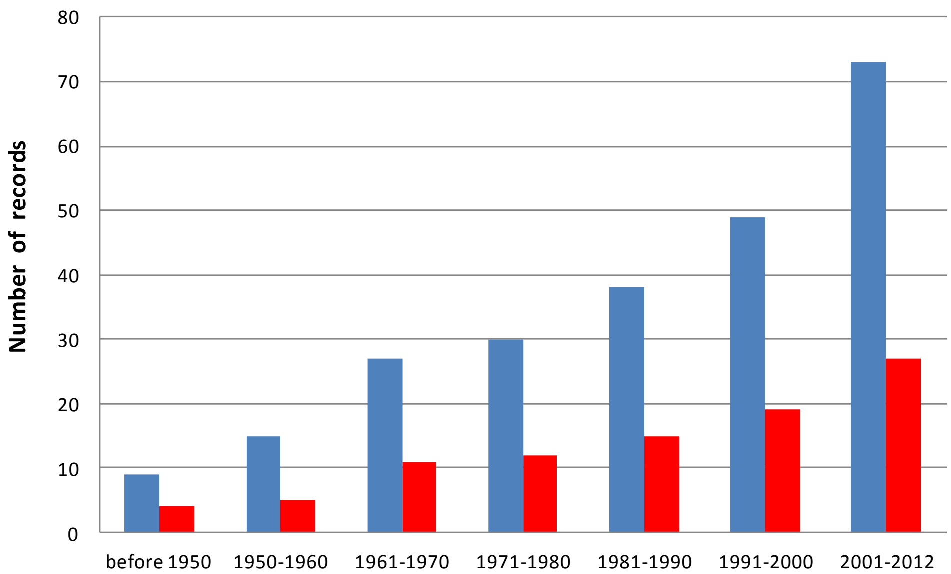

Figure 2.2. Trends in new records of alien species of fish (red bars) and invertebrate species (blue bars) in Ukrainian part of the Black Sea. Source: Aleksandrov et al., 2013

Table 2.2. Black List of aquatic invasive species of the Black Sea (invertebrates). Source: Aleksandrov et al., 2013

Groups/Species	Actual/Potential Impacts
Macroinvertebrates	
Mnemiopsis leidyi A. Agassiz, 1865 - comb jelly	This marine ctenophore is a predator. Dramatic reductions in zooplankton, ichthyoplankton, and zooplanktivorous fish populations in Black Sea and Caspian Sea have been attributed to the comb jelly Significant economic losses for the Black Sea and Caspian Sea coastal countries due to drastic decline in pelagic fish catch (estimated in hundreds of million dollars in the case of the Black Sea).
Bolinopsis vitrea (L. Agassiz, 1860) - comb jelly	This marine ctenophore is a predator. Potential impact on native zooplankton species
Hydroides dianthus (Verrill, 1873) - limy tubeworm	Fouling of marine farms and hydrotechnical constructions
Ficopomatus enigmaticus (Fauvel, 1923) - Australian tubeworm	Ecological impacts: Fouling; creation of novel bentic community
Rapana venosa (Valenciennes, 1846) - veined rapa whelk	This marine gastropod is a predator. The ecological impacts in the Black Sea have been severe: predation by this species was identified as the key reason for the decline of populations of native mussels.
Mytilopsis leucophaeata (Conrad, 1831) – Conrad's false mussel	Ecological impacts: Fouling, filter-feeder. SE impacts: Fouling of hydrotechnical constructions.
Arcuatula senhousia (Benson in Cantor, 1842)	Ecological impacts: alteration of native benthic comumunities
Oithona davisae (Ferrari F.D. & Orsi, 1984) - Asian copepod	This marine copepod may compete with native zooplankton species
Amphibalanus improvisus (Darwin, 1854) - acorn barnacle	Ecological impacts: Complex effect on community as fouler and also substrate and refugia for invertebrates. SE impacts: Fouling of hydrotechnical constructions.
Saduria entomon (Linnaeus, 1758) - sea cockroach	This large isopod is one of the most important invertebrate predators in the Baltic Sea, which fed on benthic invertebrates, mostly amphipods.
Eriocheir sinensis H. Milne Edwards, 1853 - Chineese mitten crab	Predatory crab. Potential competitor with native species for space and food especially during mass developments. Potential negative economic impacts relate to damage nets by feeding on fishes caught in traps and nets; burrowing activities of crabs result in increased erosion of dikes; they can also clog up industrial water intake filters during mass occurrences.
Hemigrapsus sanguineus (de Haan, 1835) - Japanese shore crab	Predatory crab. Potential impact on native benthic species
Rhithropanopeus harrisii (Gould, 1841) – Harris mud crab	Competes the native species of similar feeding type
Dyspanopeus sayi (Smith, 1869)	Predatory crab. Ecological impacts: Predation of native molluscs. SE impacts: predation of cultured bivalves
Palaemon macrodactylus Rathbun, 1902 -oriental shrimp	Predatory shrimp. Potential impact on native zooplankton and benthic species

In the meantime, negative ecological and economic consequences of continuing introductions of IAS in the Black Sea can be significant. Most impacting IAS for the Black Sea include North American ctenophore *Mnemiopsis leidyi*, which invaded sea at the end of last century with ballast waters of ships (for details see also EnviroGRIDS_D5.10), and Asian predatory gastropod *Rapana venosa,* responsible for decline in populations of native mussel species. Other potentially harmful invasive species from the Black List include Atlantic ctenophore *Bolinopsis vitrea,* Atlantic isopod *Saduria entomon,* Chineese mitten crab *Eriocheir sinensis,* Japanese shore crab *Hemigrapsus sanguineus*, oriental shrimp *Palaemon macrodactylus*, Asian copepod *Oithona davisae* (Table 2.2). These species are known as able to cause severe negative impacts on natural biodiversity, and relevant management options should be developed to control them (Aleksandrov et al., 2013).

Information on these species was delivered to the level of decision makers via relevant publications in the project supported REABIC journals (Kvach 2009; Micu and Niţă 2009; Raykov et al., 2010; Vladymyrov et al., 2011; Öztürk et al., 2011; Temnykh and Nishida 2012; Aleksandrov et al., 2013; Mihneva and Stefanova 2013; Snigirev et al., 2013) and Early Warning Module of the Black Sea IAS management DSS (see in section 2.4 of this report).

2.3.2. Danube River basin case study

The Danube River basin is a part of the European Southern inland water Invasion Corridor (Black Sea - Danube-Main/Danube Canal - Main-Rhine - North Sea waterway), one of Europe's four most important routes for invasive species (Figure 1). The river is therefore exposed to intensive colonisation of invasive species and further spreading in both north-west and south-east directions throughout the basin.

Extensive literature survey indicated drastic increase in new records of alien species of fish and macroinvertebrates in Danube and its tributaries during last decade (Figure 2.3), which is most likely can be related to intensive shipping along this inland waterway of international significance (Zoric et al., 2013; Paunovic et al., unpubl. data).

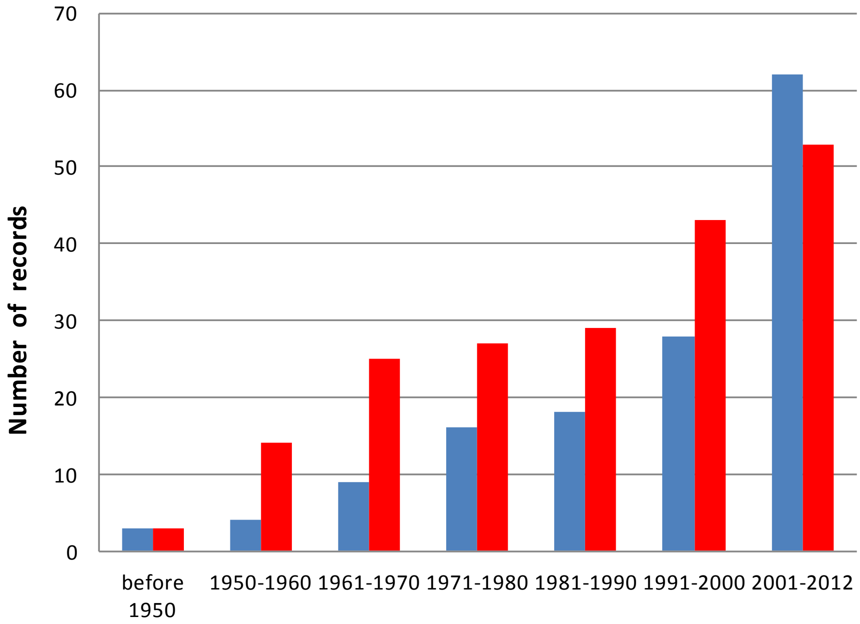

Figure 2.3. Trends in new records of alien species of fish (red bars) and macroinvertebrate (blue bars) species in Danube River basin (all new records for Lower, Middle and Upper Danube, Tisa and Sava rivers). Source: Zoric et al., 2013; Paunovich et al., unpubl.

The Black List of invasive aquatic species for Danube River basin includes 27 species of invasive plants, macroinvertebrates and fishes (Table 2.3). Most impacting IAS for the Danube River basin include: the pathogenic Oomycete pseudofungus, *Aphanomyces astaci* (crayfish plague), invasive mussels *Dreissena bugensis* (quagga mussel) and *Dreissena polymorpha* (zebra mussel), invasive crustaceans *Dikerogammarus villosus* (killer shrimp), *Chelicorophium curvispinum* (Caspian mud shrimp), *Orconectes limosus* (spinycheek crayfish) and *Eriocheir sinensis* (Chineese mitten crab), and invasive fish - *Ctenopharyngodon idella* (grass carp), *Neogobius melanostomus* (round goby), *Perccottus glenii* (Chinese sleeper), *Carassius gibelio* (Prussian carp), *Lepomis gibbosus* (pumpkinseed), *Micropterus salmoides* (largemouth bass), and *Pseudorasbora parva* (topmouth gudgeon) (brief descriptions of their impacts are provided in Table 2.3). These species are known as able to cause severe negative impacts on natural biodiversity, and relevant management options should be developed to control those (Zoric et al., 2013).

Information on invasive species in Danube River basin was delivered to the level of decision makers via relevant publications in the project supported REABIC journals (Yuryshynets and Krasutska 2009; Lajtner and Crnčan 2011; Piria et al., 2011; Zoric et al., 2011; Kvach 2012; Schrimpf et al., 2012; Zoric et al., 2013) and Early Warning Module of the Black Sea IAS management DSS (see in section 2.4 of this report).

Table 2.3. Black List of aquatic invasive species of the Danube River basin. Most impacting species indicated by bold font. Source: Zoric et al., 2013; Paunovic et al., unpubl. data et al., 2013

Groups/Species	Actual/Potential Impacts
Pathogens	
Aphanomyces astaci Schikora 1906 - crayfish plague	This Oomycete pseudofungus is the aetiologic agent for the disease which is known as crayfish plague. It destroys European crayfish species in all infected watersheds. Relict populations survive, but when populations recover a further mass mortality will occur.
Invasive plants	
Eichhornia crassipes (Mart.) Solms - water hyacinth	One of the world's worst weeds, it has a detrimental impact on water use by humans, primarily in tropical and subtropical areas. In drainage canals it may reduce the flow, which can result in flooding and damage to canal banks and structures. Water flow patterns have been disrupted in utility cooling reservoirs.
Invasive macroinvertebrates	
Branchiura sowerbyi Beddard, 1892	Competes with native species for resources. Presence of this species could disturb relations within benthic community.
Hypania invalida (Grube, 1860)	Competes with native species for resources. Presence of this species could disturb relations within benthic community.
Potamopyrgus antipodarum (J.E. Gray, 1843) - New Zealand mudsnail	Competes with native species for space and resources, high consumption rate of primary production, reduction in the colonization ability of other invertebrates
Corbicula fluminea (Müller, 1774) - Asian clam	Competes with other filter feeding bivalves (unionids) and with snails feeding on organics in sediment s by pedal feeding
Sinanodonta woodiana (Lea, 1834) - Chinese pond mussel	Competes with other filter feeding bivalves, may carry parasites.
Dreissena bugensis Andrusov, 1897 - quagga mussel	Competes the native species of similar feeding type.
Dreissena polymorpha (Pallas, 1771) - zebra mussel	Competes the native species of similar feeding type. The species slows down the eutrophication processes, indirectly favours the blooms of blue green algae, increases water transparency and ameliorate the conditions for benthic macro-vegetation
Echinogammarus trichiatus (Martynov, 1932)	Predator. Potential impact on native invertebrate species.
Obesogammarus obesus (Sars, 1894)	Predator. Potential impact on native invertebrate species.
Echinogammarus ischnus (Stebbing, 1899)	Predator. Potential impact on native invertebrate species.
Dikerogammarus villosus (Sowinsky, 1894) - killer shrimp	Predator. Potential impact on native invertebrate species. It locally eliminates other gammarid species through competition and predation. There have been some observations of the species eating fish eggs or attacking small fishes.
Dikerogammarus haemobaphes (Eichwald, 1841)	Predator. Potential impact on native invertebrate species.
Chelicorophium curvispinum (G.O. Sars, 1895) - Caspian mud shrimp	This species is known to cause ecosystem changes due to mass development. May cause local extinction of native macroinvertebrate species.
Orconectes limosus (Rafinesque, 1817) - spinycheek crayfish	Predator. Eliminates native crayfish via completion and as carrier of crayfish plague.
Eriocheir sinensis H. Milne Edwards, 1853 - Chineese mitten crab	Predator. Potential competitor with native species for space and food especially during mass developments. Potential negative economic impacts relate to damage nets by feeding on fishes caught in traps and nets; burrowing activities of crabs result in increased erosion of dikes; they can also clog up industrial water intake filters during mass occurrences.
Invasive fish species	
Ameiurus melas Rafinesque, 1820 - black bullhead	competition for food resources, potentially able to replace native fish species
Ameiurus nebulosus Lesueur, 1819 - brown bullhead	competition for food resources, potentially able to replace native fish species
Hypophthalamichthys molitrix Vallenciennes, 1844 – silver carp	Potentially may alter food webs of natural ecosystems
Ctenopharyngodon idella Vallenciennes, 1844 – grass carp	Grass carps can remove a large percentage of the aquatic vegetation, which causes ecosystem-level impacts
Neogobius melanostomus (Pallas, 1814) - round goby	Compete with native fish for food resources, habitat and spawning sites
Perccottus glenii Dybowski, 1877 - Chinese sleeper	Predator, feeding on native fish and amphibians.
Carassius gibelio Bloch, 1782 - Prussian carp	Compete with native fish for food resources, habitat and spawning sites.
Lepomis gibbosus Linnaeus, 1758 - pumpkinseed	This predatory fish can occur in very high numbers and impact the native fauna by feeding on aquatic invertebrates, larvae of amphibians and fish eggs and fry. It can have a negative impact on zooplankton composition.
Micropterus salmoides Lacepede, 1802 - largemouth bass	Predator of fish, may cause decline in native fish species
Pseudorasbora parva Temnick and Schlegel, 1846 - topmouth gudgeon	The species is generally regarded as a pest as its very high reproductive rate produces dense populations, which compete with fry of other species.

2.3.3. Dnieper River basin case study

The Dnieper River basin is a part of the European Central inland water Invasion Corridor (Black Sea - Dnieper River – Pripyat River – Bug/Pripyat Canal – Bug River - Baltic Sea waterway), and serves also as Europe's important route for IAS (Figure 2.1). As other European navigable waterways, assessment units of the Dnieper River are vulnerable to IAS colonization and play an important role in spreading of non-native species.

Analysis of trends in introductions of non-native species in assessments units of this area revealed rather high rates of non-native fish and invertebrate species introductions during last decades, averaging 6 fish species and 10 invertebrate species introductions per 10 years (Figure 2.4), primarily as a result of shipping activities and natural spread from adjacent contaminated areas.

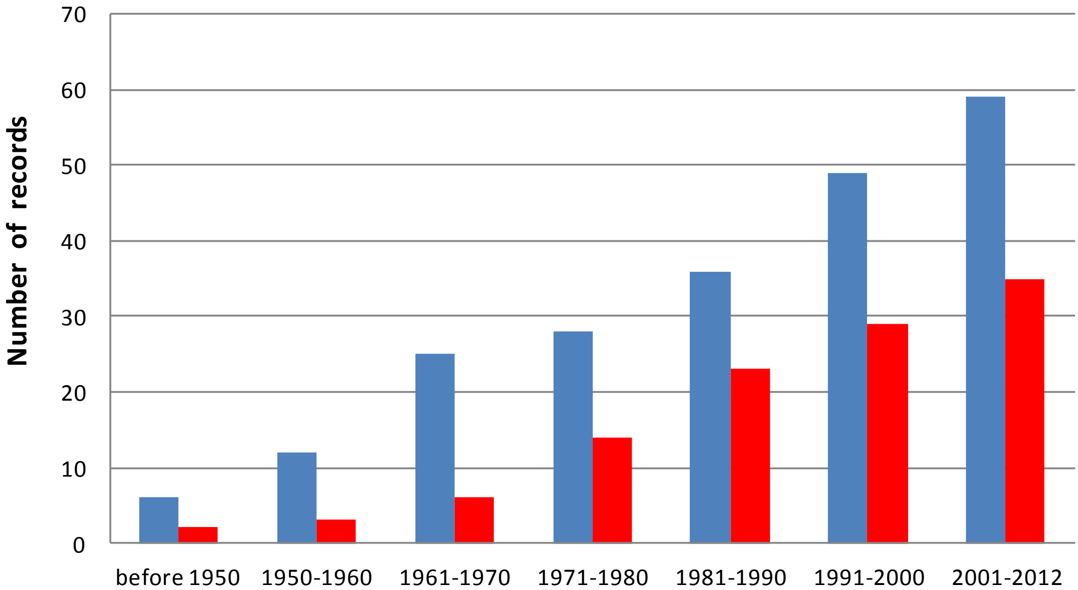

Figure 2.4. Trends in new records of alien species of fish (red bars) and macroinvertebrate (blue bars) species in the Dnieper River basin (all new records for Dnieper-Bug Liman, River Dnieper Delta and Kahovka Reservoir, Zaporozhje, Dneprodzerzhinsk and Kremenchug reservoirs, Kanev and Kiev Reservoir, upper Dniepr River, Pripyat River). Source: Semenchenko et al., 2013a

The Black List of invasive aquatic species for Dnieper River basin includes 24 species of invasive plants, macroinvertebrates and fishes (Table 2.4). Most impacting IAS for the Dnieper River basin include: invasive aquatic plants *Elodea canadensis* (Canadian waterweed) and *Elodea nuttallii* (western waterweed), invasive mussels *Dreissena bugensis* (quagga mussel) and *Dreissena polymorpha* (zebra mussel), invasive crustaceans *Dikerogammarus villosus* (killer shrimp), *Chelicorophium curvispinum* (Caspian mud shrimp), *Hemimysis anomala* (bloody-red shrimp) and *Eriocheir sinensis* (Chineese mitten crab), and invasive fish - *Ctenopharyngodon idella* (grass carp), *Neogobius melanostomus* (round goby), *Neogobius melanostomus* (round goby), *Perccottus glenii* (Chinese sleeper), *Carassius gibelio* (Prussian carp), *Lepomis gibbosus* (pumpkinseed), and *Pseudorasbora parva* (topmouth gudgeon) (brief descriptions of their impacts are provided in Table 2.4). These species are known as able to cause severe negative impacts on natural biodiversity, and relevant management options should be developed to control them (Semenchenko et al., 2013a).

As a result of successful establishment of IAS in the upper Dniepr River and its tributary Pripyat River, all locations of these rivers, sampled during project-supported biological survey in August 2011, were found as biologically contaminated (Figure 2.5). During this survey ten alien macroinvertebrate species were recorded in the studied area, and all of them were species of Ponto-Caspian origin: crustaceans *Limnomysis benedeni, Chelicorophium curvispinum*, *Dikerogammarus vilosus*, *Dikerogammarus haemobaphes*, *Obesogammarus crassus*, *Obesogammarus obesus*, *Chaetogammarus ischnus*, *Pontogammarus robustoides*, and molluscs *Dreissena polymorpha* and *Lithoglyphus naticoides*. Most of these species belong to the Black List of invasive species (Table 2.4). Also, the dominating species in studied sites were Black List species: amphipod *D. haemobaphes* in the Pripyat River and gastropod *L. naticoides* in the Dnieper River (Semenchenko et al., 2013b).

According our estimates of Site-Specific BioContamination and corresponding ecological status of the studied locations, only two locations in the studied area had low biocontamination and “good” ecological status, and majority of studied sites were more severely biocontaminated and their ecological status ranged from “moderate” to “bad” (Figure 2.5).

Information on invasive species in Dnieper River basin was delivered to the level of decision makers via relevant publications in the project supported REABIC journals (Semenchenko et al., 2009; Mastitsky et al., 2010; Mastitsky 2012; Rizevsky et al., 2013; Semenchenko et al., 2013a,b) and Early Warning Module of the Black Sea IAS management DSS (see in section 2.4 of this report).

Table 2.4. Black List of aquatic invasive species of the Dnieper River basin. Most impacting species indicated by bold font. Source: Semenchenko et al., 2013

Groups/Species	Actual/Potential Impacts
Invasive plants	
Elodea canadensis Michx. – Canadian waterweed	Canadian waterweed is known for its ability to rapidly develop dense monospecific stands which may fill entire lakes and watercourses and change the balance of the entire ecosystem
Elodea nuttallii (Planch.) H. St. John – western waterweed	Impacts similar with Canadian waterweed.
Invasive macroinvertebrates	
Cordylophora caspia (Pallas, 1771) - freshwater hydroid	This freshwater hydroid may compete with native species for resources and may cause economic damage via fouling of ships and hydrotechnical constructions
Urnatella gracilis Leidy, 1851 - freshwater entoproct	This freshwater species may compete with native species for resources and may cause economic damage via fouling of ships and hydrotechnical constructions
Lithoglyphus naticoides (Pfeiffer, 1828) - gravel snail	This freshwater gastropod may carry parasites for fish and human
Potamopyrgus antipodarum (J.E. Gray, 1843) - New Zealand mudsnail	This freshwater gastropod competes with native species for space and resources, high consumption rate of primary production, reduction in the colonization ability of other invertebrates
Dreissena polymorpha (Pallas, 1771) - zebra mussel	This freshwater mussel may cause changes in biodeposition and sedimentation; elimination of native bivalves; complex impact on abundance, taxonomic richness and size of other animals in macroinvertebrate communities; strong positive effects on scrapers and deposit-feeding taxa and strong negative effects on filter-feeding taxa; creation of added grazing area and spatial refugia from predators. Fouling of hydrotechnical constructions.
Dreissena bugensis Andrusov, 1897 - quagga mussel	Competes the native species of similar feeding type, other impacts similar with zebra mussel
Pontogammarus robustoides G.O. Sars, 1894	This freshwater amphipod is a predator, and may cause decline in native species of invertebrates
Obesogammarus obesus (Sars, 1894)	Predator. Potential impact on native invertebrate species.
Obesogammarus crassus (G.O. Sars, 1894)	Predator. Potential impact on native invertebrate species.
Echinogammarus ischnus (Stebbing, 1899)	Predator. Potential impact on native invertebrate species.
Dikerogammarus villosus (Sowinsky, 1894) - killer shrimp	Predator. Potential impact on native invertebrate species. It locally eliminates other gammarid species through competition and predation. There have been some observations of the species eating fish eggs or attacking small fishes.
Dikerogammarus haemobaphes (Eichwald, 1841)	Predator. Potential impact on native invertebrate species.
Chelicorophium curvispinum (G.O. Sars, 1895) - Caspian mud shrimp	This species is known to cause ecosystem changes due to mass development. May cause local extinction of native macroinvertebrate species.
Hemimysis anomala G.O.Sars, 1907 – Bloody-red shrimp	Predator. Potential impact on native invertebrate species, specifically zooplankton
Rhithropanopeus harrisii (Gould, 1841) – Harris mud crab	Competes the native species of similar feeding type
Eriocheir sinensis H. Milne Edwards, 1853 - Chineese mitten crab	Predator. Potential competitor with native species for space and food especially during mass developments. Potential negative economic impacts relate to damage nets by feeding on fishes caught in traps and nets; burrowing activities of crabs result in increased erosion of dikes; they can also clog up industrial water intake filters during mass occurrences.
Invasive fish species	
Neogobius melanostomus (Pallas, 1814) - round goby	Compete with native fish for food resources, habitat and spawning sites
Proterorhinus semilunaris (Heckel, 1837) - western tubenose goby	Compete with native fish for food resources, habitat and spawning sites
Perccottus glenii Dybowski, 1877 - Chinese sleeper	Predator, feeding on native fish and amphibians.
Carassius gibelio Bloch, 1782 - Prussian carp	Compete with native fish for food resources, habitat and spawning sites.
Lepomis gibbosus Linnaeus, 1758 - pumpkinseed	This predatory fish can occur in very high numbers and impact the native fauna by feeding on aquatic invertebrates, larvae of amphibians and fish eggs and fry. It can have a negative impact on zooplankton composition.
Pseudorasbora parva Temnick and Schlegel, 1846 - topmouth gudgeon	The species is generally regarded as a pest as its very high reproductive rate produces dense populations, which compete with fry of other species.

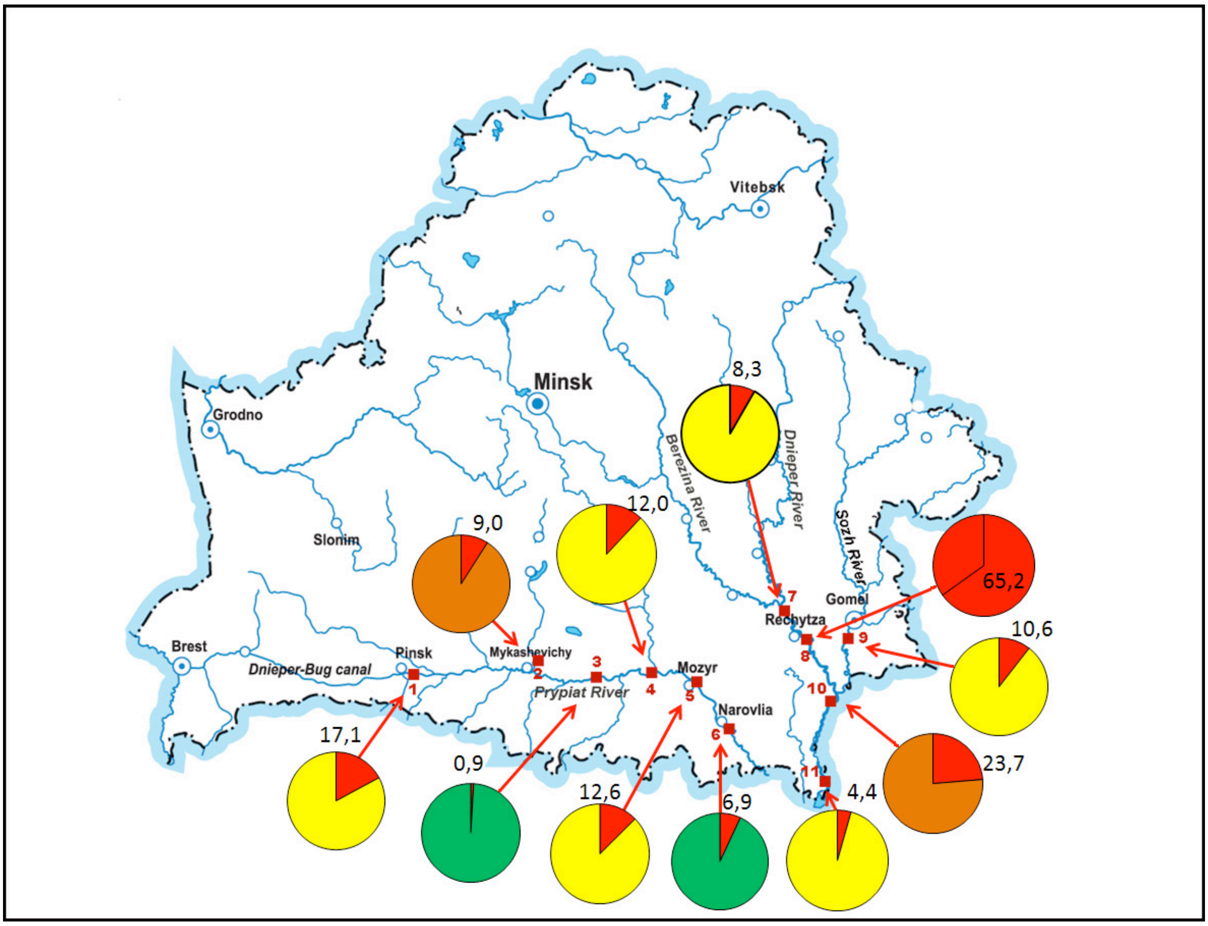

Figure 2.5. Results of assessment of biocontamination of the upper Dnieper River and Pripyat River in August 2011. Colours of main parts of pie diagrams indicate estimated classes of Site-Specific BioContamination and related estimates of ecological status of studied sites (see classes ranges in Table 2.1). Secondary slices of pie diagrams in red colour indicate proportion of alien species in total abundance of macroinvertebrate species. Numbers at secondary slices, in %, indicate abundance contamination index (ACI, see classes ranges in Table 2.1). Source: Semenchenko et al., 2013b.

2.3.4. Don River basin case study

The Don River basin is a part of the European Northern inland water Invasion Corridor (Black Sea – Azov Sea - Don River – Volga-Don Canal – Volga River – Volga-Baltic Canal – Lake Onega- Lake Ladoga – Neva River - Baltic Sea waterway and Black Sea – Azov Sea - Don River – Volga-Don Canal – Volga River – Caspian Sea waterway, Figure 2.1). Assessment units of the Don River basin were also found as vulnerable to colonization by non-native species. Analysis of trends in introductions of non-native species in assessments units of Don River basin revealed drastic increase in rates of non-native fish and invertebrate species introductions during last decades, peaking 9 fish species and 23 invertebrate species introductions during last 12 years (Figure 2.6). Most likely, this is a consequence of intense ship traffic and climate changes.

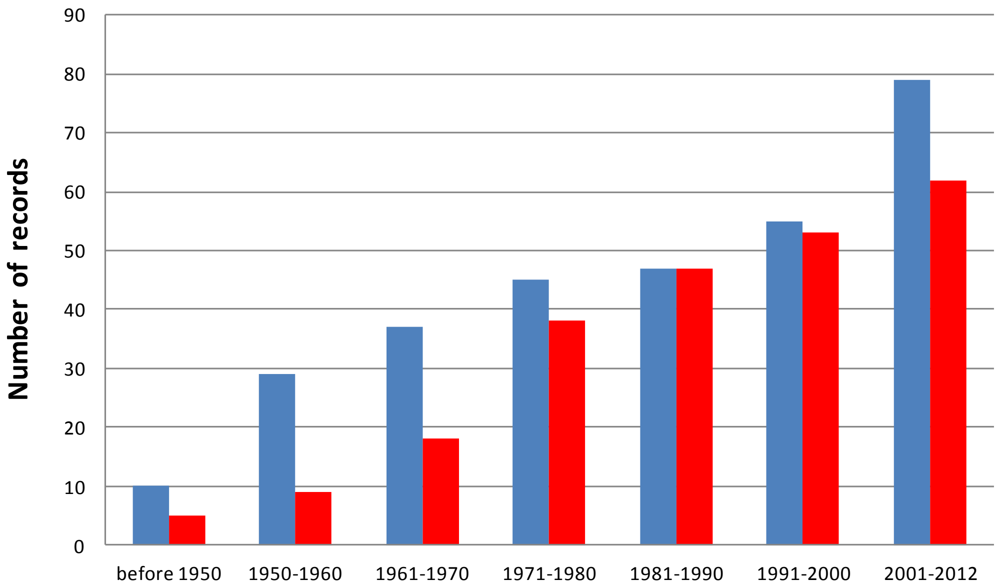

Figure 2.6. Trends in new records of alien species of fish (red bars) and macroinvertebrate (blue bars) species in the Don River basin (all new records for Lower Don River, Tsymlyansk Reservoir, Upper and Middle Don River basin, Manych River basin, Severskii Donets River basin). Source: Prokin et al., 2013a

Black List of invasive species for the Don River basin includes 18 species of invasive plants, macroinvertebrates and fishes, which currently spreading in the basin and able to affect negatively natural biodiversity of the area (Table 2.5). Most impacting IAS for the Don River basin include: invasive aquatic plant *Elodea canadensis* (Canadian waterweed), invasive mussel *Dreissena bugensis* (quagga mussel), invasive crustaceans *Dikerogammarus villosus* (killer shrimp), *Dikerogammarus caspius* and *Eriocheir sinensis* (Chineese mitten crab), and invasive fish - *Neogobius melanostomus* (round goby), *Neogobius melanostomus* (round goby), *Perccottus glenii* (Chinese sleeper), *Carassius gibelio* (Prussian carp), *Lepomis gibbosus* (pumpkinseed), and *Pseudorasbora parva* (topmouth gudgeon) (brief descriptions of their impacts are provided in Table 2.5). These species are known as able to cause severe negative impacts on natural biodiversity, and relevant management options should be developed to control them (Prokin et al., 2013a).

Table 2.5. Black List of aquatic invasive species of the Don River basin. Most impacting species indicated by bold font. Source: Prokin et al., 2013

Groups/Species	Actual/Potential Impacts
Invasive plants	
Elodea canadensis Michx. – Canadian waterweed	Canadian waterweed is known for its ability to rapidly develop dense monospecific stands which may fill entire lakes and watercourses and change the balance of the entire ecosystem
Invasive macroinvertebrates	
Cordylophora caspia (Pallas, 1771) - freshwater hydroid	This freshwater hydroid may compete with native species for resources and may cause economic damage via fouling of ships and hydrotechnical constructions
Urnatella gracilis Leidy, 1851 - freshwater entoproct	This freshwater species may compete with native species for resources and may cause economic damage via fouling of ships and hydrotechnical constructions
Potamopyrgus antipodarum (J.E. Gray, 1843) - New Zealand mudsnail	This freshwater gastropod competes with native species for space and resources, high consumption rate of primary production, reduction in the colonization ability of other invertebrates
Dreissena bugensis Andrusov, 1897 - quagga mussel	Competes the native species of similar feeding type, and may cause changes in biodeposition and sedimentation; elimination of native bivalves; complex impact on abundance, taxonomic richness and size of other animals in macroinvertebrate communities
Obesogammarus crassus (G.O. Sars, 1894)	Predator. Potential impact on native invertebrate species.
Pontogammarus robustoides G.O. Sars, 1894	This freshwater amphipod is a predator, and may cause decline in native species of invertebrates
Echinogammarus ischnus (Stebbing, 1899)	Predator. Potential impact on native invertebrate species.
Dikerogammarus villosus (Sowinsky, 1894) - killer shrimp	Predator. Potential impact on native invertebrate species. It locally eliminates other gammarid species through competition and predation. There have been some observations of the species eating fish eggs or attacking small fishes.
Dikerogammarus haemobaphes (Eichwald, 1841)	Predator. Potential impact on native invertebrate species.
Dikerogammarus caspius (Pallas, 1771)	Predator. Potential impact on native invertebrate species.
Rhithropanopeus harrisii (Gould, 1841) – Harris mud crab	Competes the native species of similar feeding type
Eriocheir sinensis H. Milne Edwards, 1853 - Chineese mitten crab	Predator. Potential competitor with native species for space and food especially during mass developments. Potential negative economic impacts relate to damage nets by feeding on fishes caught in traps and nets; burrowing activities of crabs result in increased erosion of dikes; they can also clog up industrial water intake filters during mass occurrences.
Invasive fish species	
Hypophthalmichthys nobilis (Richardson, 1845) – bighead carp	Compete with native fish for food resources, habitat and spawning sites
Neogobius melanostomus (Pallas, 1814) - round goby	Compete with native fish for food resources, habitat and spawning sites
Carassius gibelio Bloch, 1782 - Prussian carp	Compete with native fish for food resources, habitat and spawning sites.
Lepomis gibbosus Linnaeus, 1758 - pumpkinseed	This predatory fish can occur in very high numbers and impact the native fauna by feeding on aquatic invertebrates, larvae of amphibians and fish eggs and fry. It can have a negative impact on zooplankton composition.
Perccottus glenii Dybowski, 1877 - Chinese sleeper	Predator, feeding on native fish and amphibians.
Pseudorasbora parva Temnick and Schlegel, 1846 - topmouth gudgeon	The species is generally regarded as a pest as its very high reproductive rate produces dense populations, which compete with fry of other species.

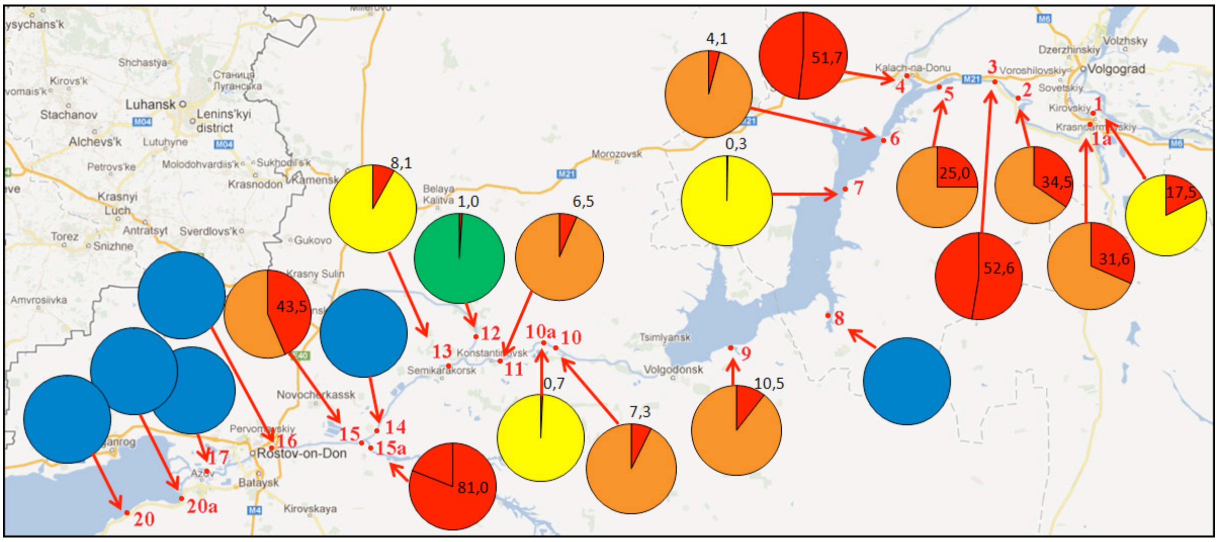

Figure 2.7. Results of assessment of biocontamination of the lower Don River in August 2011. Colours of main parts of pie diagrams indicate estimated classes of Site-Specific Biocontamination and related estimates of ecological status of studied sites (see classes ranges in Table 2.1). Secondary slices of pie diagrams in red colour indicate proportion of alien species in total abundance of macroinvertebrate species. Numbers at secondary slices, in %, indicate abundance contamination index (ACI, see classes ranges in Table 2.1).

During our special biological survey conducted on the lower Don River in August 2011, we estimated site-specific biocontamination in 22 locations (Prokin et al., 2013b). This survey revealed high level of biological contamination of many locations in the river (Figure 2.7). Specifically, we recorded 8 alien macroinvertebrate species: mollusks *Dreissena bugensis* (guagga mussel), *Theodoxus astrachanicus*, *Potamopyrgus antipodarum*, *Physella acuta*, crustaceans *Dikerogammarus caspius, Dikerogammarus villosus* (killer shrimp), *Pontogammarus robustoides,* and *Obesogammarus crassus.*

Majority of studied sites were biocontaminated, but we found 6 non-biocontaminated locations (Figure 2.7). According our estimates of Site-Specific BioContamination and corresponding ecological status of biocontaminated locations, most of them were severely biocontaminated and their ecological status was estimated as “poor” and “bad” (Figure 2.7).

Information on invasive species in Don River basin was delivered to the level of decision makers via relevant publications in the project supported REABIC journals (Prokin et al., 2013a, b; Zhulidov et al., 2013) and Early Warning Module of the Black Sea IAS management DSS (see in section 2.4 of this report).

2.4. Informational Support and Recommendations for the Regional Early Warning System on Invasive Species

2.4.1. Early Warning Services of the Regional Euro-Asian Biological Invasions Centre

Open informational resources are important for support of decision making on invasive alien species (IAS). Before start of EnviroGRIDS project, the open information resources on invasive alien species IAS in the Black Sea basin countries were limited to the regional *Mnemiopsis leidyi* database (Vladymyrov et al., 2011), the database of aquatic invaders of Belarus (Mastitsky et al., 2010) and the Ukrainian node of the GloBallast programme (GloBallastUkraine 2011). However, mechanisms of regular updates of these resources with new information are lacking and their value for early warning purposes is limited.

With the support of the *enviroGRIDS* project, during 2009-2013 we developed demonstration version of the regional risk assessment-based Decision Support and Early Warning System on IAS for the Black Sea basin, which is based on online information management tools available at the Regional Euro-Asian Biological Invasions Centre (REABIC) website (http://www.reabic.net/), including instruments for early warning (Panov et al., 2012; Panov et al., 2013).

REABIC is serving as an independent regional data centre for invasive alien species (IAS) and recognised international repository of geo-referenced record data on IAS (Figure 2.8). REABIC is currently focusing on elaboration of effective mechanisms of online open access to the datasets of geo-referenced IAS monitoring data. Specifically, REABIC provides services for data holders in the protection of their author rights on IAS related information via timely publication of their papers in the international open access thematic journals *Aquatic Invasions, BioInvasions Records*, and *Management of Biological Invasions* established by REABIC (http://www.reabic.net/journals/). These thematic journals include a peer-reviewing system as the mechanism of quality control of IAS data, available after their publication in the online information system of REABIC. These scientific journals, as part of the information system of REABIC, serve to provide a unique opportunity to develop early warning systems, based on the most recent geo-referenced records of IAS (Panov et al., 2011; Lucy and Panov 2012; Panov et al., 2012; Panov et al., 2013). In combination with other REABIC-based online services, including the European Research and Management Network on Aquatic Invasive Species (ERNAIS) experts database (http://www.reabic.net/ZnExp.aspx), REABIC also provides a virtual platform for linking the international research community and general public, managers and decision-makers (Figure 2.9). REABIC is registered as GEOSS component, and is serving as a partner organisation and data provider for the Global Biodiversity Information Facility (GBIF) and developing European Alien Species Information Network (EASIN, http://easin.jrc.ec.europa.eu/Partners , Figure 2.8).

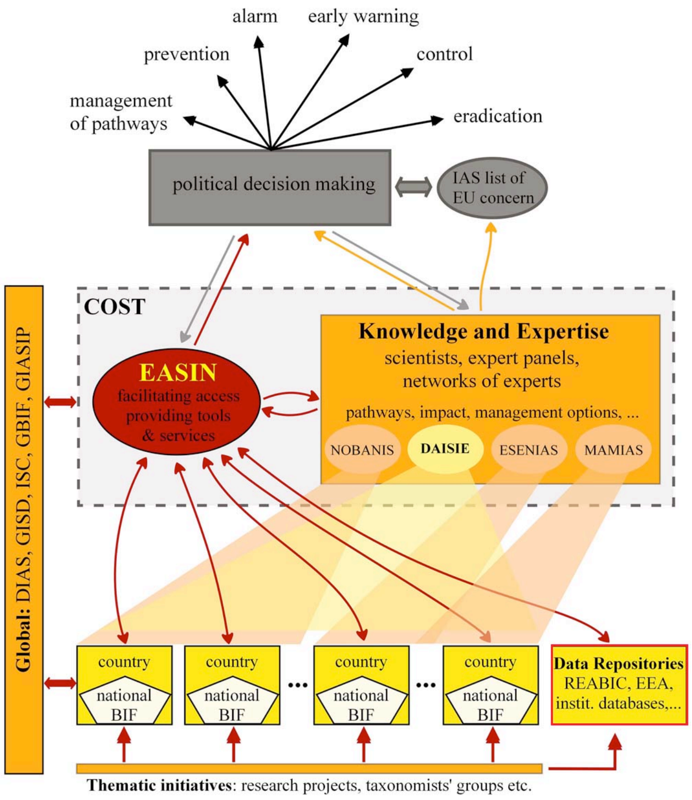

Figure 2.8. The proposed organizational chart of all the players in an developing EU information network for alien species aiming to provide the required knowledge and scientific advice to support political decision making. Red arrows indicate flow of data and information; orange arrows denote scientific advice; grey arrows stand for demands for policy support; black arrows indicate the main issues that have to be addressed by decision makers. After Katsanevakis et al., 2013.

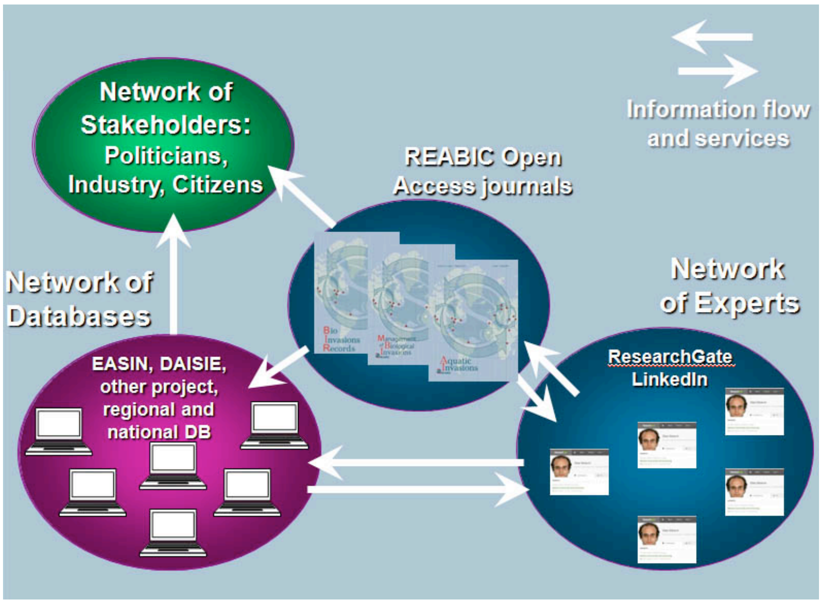

Figure 2.9. REABIC Open Access journals as an important part of the developing European information and early warning system on IAS**.**

Figure 2.10. Early Warning Module of the Black Sea IAS management DSS, including map with selected records of Invasive Alien Species in the Black Sea Basin published in Aquatic Invasions in 2009-2013. Numbers indicate: 1 – First record of predatory isopod *Saduria entomon* in coastal waters of the Black Sea (Kvach 2009) , 2 – First record of parasitic worm *Aspidogaster conchicola* in the Black Sea basin (Yuryshynets and Krasutska 2009) , 3 – First record of Asian prawn *Palaemon macrodactylus* in coastal waters of the Black Sea (Micu and Niţă 2009); 4 – First record of Asian prawn *Palaemon macrodactylus* in Bulgaria (Raykov et al., 2010), 5 – First record of Japanese shore crab *Hemigrapsus sanguineus* in coastal waters of the Black Sea (Micu et al., 2010), 6 – First record of subtropical ctenophore *Bolinopsis vitrea* in coastal waters of the Black Sea (Öztürk et al., 2011), 7 – First record of Asian clam *Corbicula fluminea* in Moldova (Munjiu and Shubernetski 2010), 8 – First record of the Ponto-Caspian amphipod *Echinogammarus trichiatus* for the Middle-Danube (Borza 2009), 9 – First record of Chinese pond mussel *Sinanodonta woodiana* in Croatia (Lajtner and Crnčan 2011), 10 – First record of round goby *Neogobius melanostomus* in Croatia (Piria et al., 2011), 11 – Ponto-Caspian polychaete *Hypania invalida* in inland waters of Serbia (Zoric et al., 2011), 12 - First records of Chinese sleeper *Perccottus glenii* in lower Danube River (Kvach 2012; Reshetnikov 2013); 13 - First records of Asian copepod *Oithona davisae* in coastal waters of Black Sea (Temnykh, Nishida 2012; Mihneva, Stefanova 2013); 14 - First record of crayfish plague *Aphanomyces astaci* in lower Danube River (Schrimpf et al., 2012); 15 - First records of guagga mussel *Dreissena bugensis* in Danube River (Heiler et al., 2013 in press) and in lower Don River (Zhulidov et al., 2013; Prokin et al., 2013); 16 - New records of killer shrimp *Dikerogammarus villosus* in the upper Dnieper River and lower Don River (Semenchenko et al., 2009, 2013; Prokin et al., 2013); 17 - New records of Caspian amphipod *Dikerogammarus caspius* in the lower Don River (Prokin et al., 2013); 18 - New records of Ponto-Caspian amphipod *Pontogammarus robustoides* in the upper Dnieper River and lower Don River (Semenchenko et al., 2009, 2013; Prokin et al., 2013); 19 - New records of Ponto-Caspian amphipod *Obesogammarus crassus* in the upper Dnieper River and lower Don River (Semenchenko et al., 2009, 2013; Prokin et al., 2013); 20 - First records of Ponto-Caspian stellate tadpole-goby *Benthophilus stellatus* in the upper Don River (Rizevsky et al., 2013). Source: http://www.reabic.net/DSS_BlackSeaBasin/EarlyWarning.aspx

The current version of the early warning module of the REABIC-based Black Sea basin IAS management DSS is available at the Early Warning and Rapid Response web page (http://reabic.net/DSS_BlackSeaBasin/EarlyWarning.aspx) includes description of our general approach to early warning and links to relevant international documents, including the European Environment Agency technical report "Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe" (EEA 2010) and recent recommendations of the European Commission Working Group on Early Warning and Rapid Response (Figure 2.10).

Also, the early warning module of the Black Sea basin IAS management DSS includes a map of the Black Sea basin with first records of aquatic IAS in the Black Sea Basin published in the REABIC open access journals *Aquatic Invasions* and *BioInvasons Records* in 2009-2013 (Figure 2.10). During this period with support of *enviroGRIDS* we focused on rapid publication of case studies on new records of invasive species in REABIC open access journals as demonstration activity in support of timely transfer of this information to the level of decision-makers (Lucy and Panov 2012). As indication of success of this activity, recently REABIC was recognized as main regional repository of IAS related data, interlinked with the online database of the European Alien Species Information Network (http://easin.jrc.ec.europa.eu/) – an important informational source supporting EU policy on IAS (Katsanevakis et al., 2013; Figure 2.8). Example of presentation of REABIC-based geo-referenced record data for invasive species in the online REABIC and EASIN GIS applications are shown in Figure 2.11. The information available via online EASIN information management tools is supposed to be further used for IAS-related decision-making on EU level.

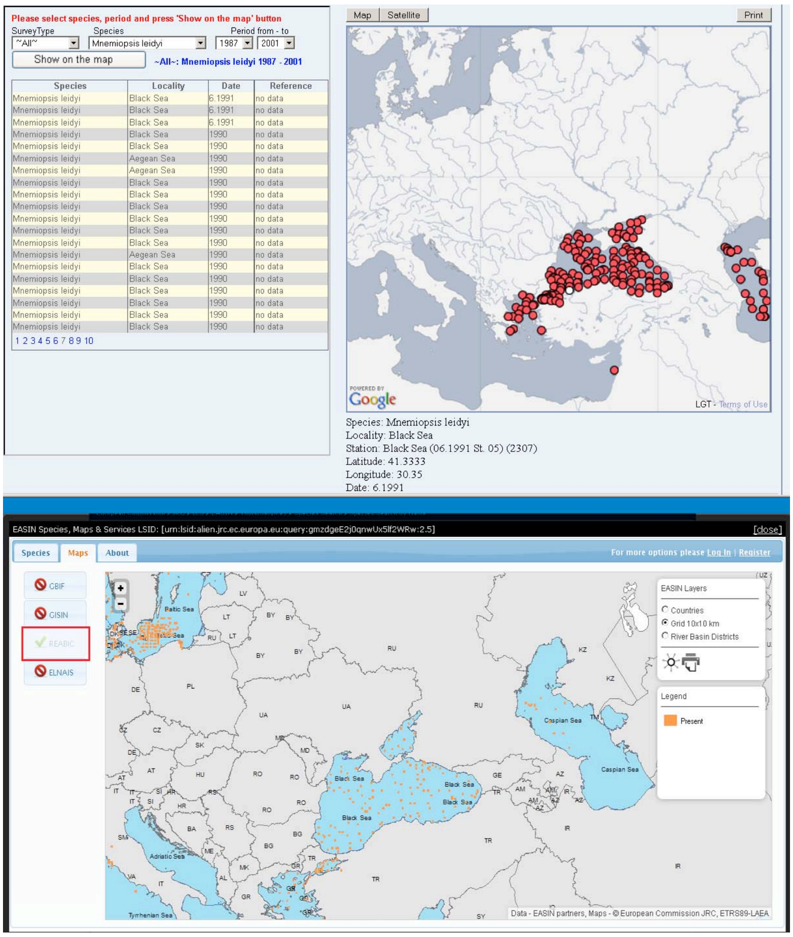

Figure 2.11. Screenshots of interfaces of REABIC (upper plate) and EASIN (bottom plate) online GIS applications showing geo-referenced record data for American invasive ctenophore *Mnemiopsis leidyi* in the Black Sea, initially deposited in REABIC database.

2.4.2. Recommendations for the Regional Early Warning System on Invasive Species

The urgent need for regional open information system on IAS in the Ponto-Caspian area in support of decision-making has been justified almost a decade ago (Panov, 2004), but available open information resources on IAS in the region and their value for early warning purposes are still limited (see in sections 2.1 and 2.4.1 of this report). However, currently a dedicated legislative instrument is being developed by the Commission (to be launched in 2013) as dictated by Action 16 of the EU Biodiversity Strategy, and European countries and their relevant institutions have or will have, under the developing EU legislative instrument, obligations and commitments under both the European and global frameworks in respect to IAS. These include prioritising pathways for prevention, identifying the most harmful species for responses, enforcing effective early warning and rapid response mechanisms, developing indicators of trends and responses, and other management strategies (Katsanevakis et al., 2013). These ongoing political activities may facilitate development of the regional information systems on IAS, and specifically, operational early warning system on IAS.

The operational early warning system on IAS for Black Sea catchment area should include relevant monitoring system for early detection of invasive species, and relevant risk assessment and management procedures, preferably based on the online Decision Support System for management of introductions of invasive alien species (DSS). Demonstration version of relevant regional DSS has been developed with support of EnviroGRIDS project at REABIC website (details are available in EnviroGRIDS_D5.4).

Regular problems with timely open access to primary geo-referenced invasive species records data, distributed among primary data holders (scientists and citizens) is likely one of main obstacles for development of cost-effective operational early warning systems on IAS. Our activities with EnviroGRIDS project clearly demonstrated that Open Access journals may serve as cost-effective tools for timely collection and analysis (including risk assessment) of essential information on IAS. The incorporation of Open Access journals into the REABIC information system represents an innovative approach to IAS-related information management (Figure 2.8), which may resolve the issue of timely reporting of new records of invasive species (Panov et al., 2011; Lucy and Panov 2012) and this approach should be carefully considered in future attempts in development of the operational regional early warning system(systems) on IAS.

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Part 3: Case Studies for Invasive Terrestrial Plant Species (Monica Dumitraşcu, Ines Grigorescu, Gheorghe Kucsicsa , Carmen Dragotă, Mihaela Năstase, Mihai Doroftei, Marian Mierlă)

Abstract

Under the current global changes, biological invasions ranks among the most critical ecological threats to natural habitats and biodiversity due to their high adaptive capacity to wide ecological conditions and multiplication potential, thus enabling them to get through natural geographic barriers or political boundaries. Under given circumstances, the assessment of terrestrial invasive plant species (ITPS) and the key driving forces responsible for their introduction and spread in some Romanian protected areas was undertaken, namely some selected case-studies for each biogeographical region in Romania: Rodna Mountains National Park and Maramureş Mountains Natural Park (Alpine region), Mureş Floodplain Natural Park (Pannonic region), Comana Natural Park (Continetal region), Măcin Mountains National Park (Steppic region) and (Danube Delta Biosphere Reserve (Pontic region). For that purpose, in-depth cross-referencing of the biological and geographical scientific literature on the most relevant invasive terrestrial plant species in the Romanian protected areas (*Amorpha fruticosa, Acer negundo*, *Ailanthus altissima, Fallopia japonica*) was carried out. Based on the complex assessment of spatial (GIS processing of the most relevant cartographical materials: topographical, geological, hydrogeological, soil, vegetation, aerial photographs etc.) and statistical data as well as field surveys, an invasive terrestrial plant species potential distribution model (ITPS-podismod) was also developed. The model will be able to predict the distribution, spread and recurrence of ITPS in the selected protected areas. Additionally, some relevant biological indicators (abundance, frequency, ecological significance and ecological significance) in relation to its key environmental driving forces (both natural and human-induced) in selected case-studies have been undertaken. Therefore, taking into consideration the intensification of the human-induced influences in various habitats, the complex assessment of the occurrence, development and spread the main ITPS in the Romanian protected areas becomes essential task, thus having a significant contribution to the current early warning services of the Regional Euro-Asian Biological Invasions Centre information system.

3.1. Invasive Terrestrial Plant Species - general overview (IGAR)

Invasive Terrestrial Plant Species (ITPS) are considered by the *Biological Diversity Convention* as *species and subspecies introduced outside their natural habitat, both past and present, from all taxonomic groups (gametes, seeds, eggs or propagules that might survive and later reproduce)*. Additionally, the most important international bodies dealing with nature conservation (International Union for the Conservation of Nature, IUCN) underlines the real dimension of the invasive alien species environmental impact considering them as *immense, insidious and usually irreversible*.

Biological invasions pose significant treat to biodiversity and ecosystem services particularly since the *Convention on Biological Diversity's 2010 Biodiversity Target* has stimulated global initiatives to quantify the extent of biological invasions, their impact on biodiversity and the related policy responses (Reichard and Hamilton, 1997; McGeoch et al., 2010). As a consequence, are often categorized as economic, environmental, or social threats (Charles & Dukes, 2006; Bailey et al., 2007; McGeoch et al., 2010), thus becoming key components of global change (Shea and Chesson 2002; Arim et al., 2006) through their high adaptive capacity enabling them to penetrate natural geographic barriers or political boundaries (Rejmanek and Richardson, 1996; Richardson et al., 2000; Anastasiu & Negrean 2005; Anastasiu et al., 2008; Andreu and Vila 2010).

Consequently, ITPS have become successfully established over large areas in Europe causing significant environmental socio-economic damages (Pysek and Hulme 2005; Lambdon et al., 2008; Dumitraşcu et al., 2012) and, under the increasing trade and travel means the threat they produce is likely to increase (McGeoch et al., 2010). In protected areas, in particular, biological invasions are disturbing drivers for ecosystem functioning and structure, as well as for species, species communities or habitats (Hobbs & Huenneke, 1992; De Poorter et al., 2007).

Therefore, in order to exchange information and knowledge on invasive species and assure the connection to practice and policy the ***Invasive Species Specialist Group (ISSG)*** was established since 1994. ISSG is a global network in the framework of ***Species Survival Commission (SSC)*** of the **World Conservation Union (IUCN)** assuming an important role in fighting against invasive species by reducing the threats they stress upon to natural ecosystems and the native species they contain.

Prior to the development of the EU-FP6 project *Delivering Alien Invasive Species In Europe (DAISIE)*, the assessment of ITPS in Europe was based on isolated regional or local studies. Subsequently, valuable and comprehensive information in terms of scientific and institutional cooperation, data gathering and systematization etc., were added. The project gathered 19 partners from 15 nations plus a great number of contributors and was carried out by means of an international team of experts in the field of biological invasions, latest technologies in database design and display, and an extensive network of European collaborators and stakeholders. Therefore, DAISIE database contains records of 5,798 alien plant species in Europe, out of which 2,843 are alien to Europe (of extra-European origin) and the rest of 2,671 are of European origin (Lambdon et al., 2008) (Figure 3.1).

Under the global context of increasing biological invasions, the *New Strategic Plan of the Convention on Biological Diversity - Aichi Biodiversity Targets for 2011-2020* is proposing, among its strategic goals, to diminish direct pressures on biodiversity through identifying, controlling or eradicating invasive alien species and pathways as well as adopting measures to manage pathways and prevent their introduction and establishment (UN CBD Aichi Biodiversity Targets, 2010).

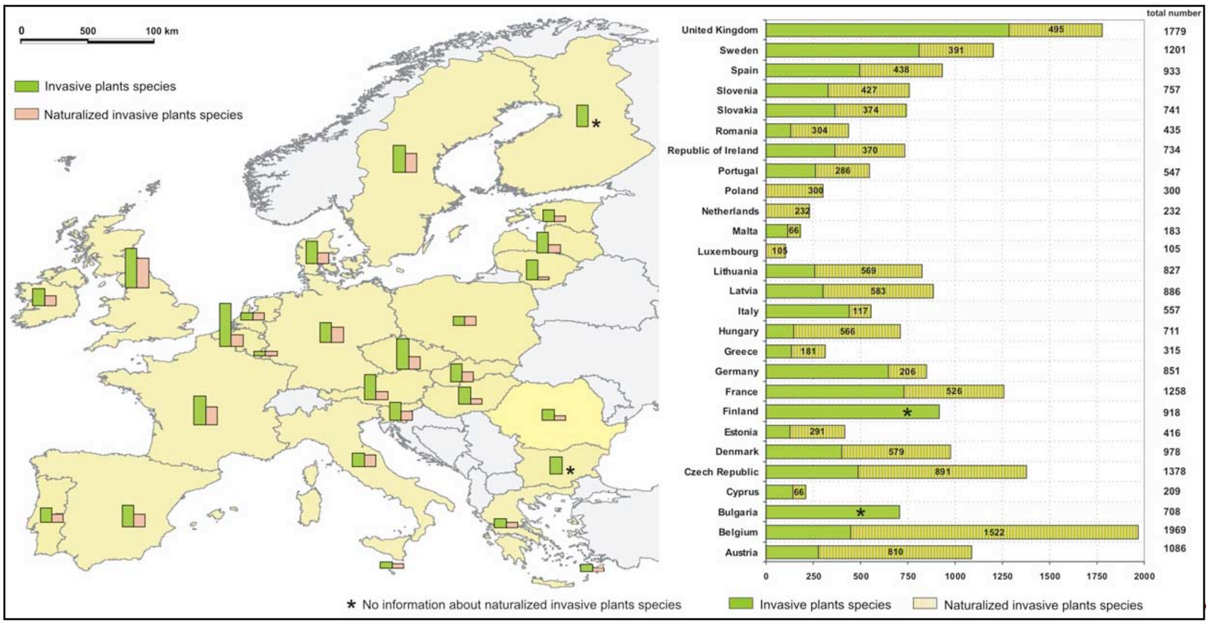


Figure 3.1. Invasive plant species in the European Union countries (processed and adapted after FP6 - Delivering Alien Invasive Species Inventories for Europe - DAISIE and Lambdon et al., 2008).

3.2. Invasive Terrestrial Plant Species in the Romanian Protected Areas (IGAR)

In Romania the first invasive plants species have been reported at the beginning of 18th century and ever since, important information was regularly displayed in several studies having a systematic and floristic character. Among these studies, one can mention a large number of recorded specimens of *Amaranthus hybridus*, between the villages Moftinul Mare, Terebeşti and Ardud (Satu Mare County), *Amaranthus viridis* in Sasca Montană (Caraş Severin County) and *Echinochloa oryzoides* in Banat (Anastasiu & Negrean, 2005). Consequently, an increased number of invasive species were identified and mentioned in different scientific works or floristic lists which were synthesized in "Flora României" vol. 1-13, (1957-1972) and more recently in "Flora IIustrată a României" (2000) (Ciocârlan, 2000).

Currently, the invasive flora of Romania includes over 400 species (13.87% of the Romanian flora) belonging to 82 families, out of which 88.27% are neophytes (which arrived into Europe after 1492) and 11.73% archaeophytes (which arrived into Europe before 1492) (Anastasiu & Negrean, 2005; Sîrbu & Oprea, 2008). According to the third National Report of Biological Diversity Convention (2005), some of the most important invasive alien tree species in Romania are: *Acer negundo, Ailanthus altisima, Amopha fruticosa, Fraxinus Americana* etc. (MODIS, 2007). Over the recent years, new alien species have continuously been reported, thus increasing the number of non-native taxa (Sîrbu & Oprea, 2008).

The most taxa found in Romania belong to families known to invade habitually zones of temperate climate: Asteraceceae (61 taxa), Brassicaceae (38 taxa), Poaceae (30 taxa). Numerous families, like Orchidaceae do not have alien representative in our flora, while others, like Amaranthaceae have almost exclusively alien representatives (Anastasiu & Negrean 2005).

Recent studies reveal that riparian zones appear to be more susceptible to invasion than other ecosystems, because periodic hydrological disturbances destroy or damage riparian vegetation creating openings that provide favourable conditions for the establishment of the invasive propagules. Moreover, rivers act like natural drivers and dispersal agents facilitating the spread of the species (Fenesi et al., 2009). For instance, some ornamental plants, such as *Echinocystis lobata*, *Helianthus tuberosus*, *Solidago canadensis*, *Solidago gigantea* subsp. *serotina* and *Rudbeckia laciniata* escaped from cultivation and they are abundant especially areas from Transylvania, Banat and Crişana where they invaded the local vegetal communities while other invasive species (*Acer negundo*, *Ailanthus altissima*, *Aster lanceolatus*, *Ambrosia artemisiifolia*, *Parthenocissus inserta*) are only scattered (Anastasiu et al., 2008).

Although Romania has ratified the Convention of Biodiversity (Rio de Janeiro, 1992) by means of law 58/1994, until now there were no important steps made, especially in terms of implementation of article 8, with respect to alien invasive species (Dumitraşcu et al., 2011a). Therefore, the qualitative and quantitative (using relevant biological indicators) assessment of ITPS species is essential in estimating potential spread and evolution pathways, undertaking proper and sustainable management decisions and mitigating impacts.

In the Romanian protected areas, among the most dangerous ITPS, the following rank first: *Elaeagnus anguistifolia*, *Amorpha fruticosa, Ailanthus altissima, Acer negundo, Robinia pseudoacacia, Fallopia japonica* etc. (Doroftei et al., 2005).

Natural Protected Areas in Romania. Under the global environmental changes and climate change, the role of protected areas in conserving biodiversity and landscape becomes increasingly important. Under the given circumstances, the growing surface of protected areas, creating corridors link between them and reducing human impact are just some of the needs for ensuring an adequate management.

Therefore, the environmental policies must be made in connection with the agricultural, energy, transport policies having as starting point the principles of sustainability restated by the Rio +20 Summit. In addition to the involvement in the decision-making process by creating an adequate legal protection of biodiversity can not be achieved without the support of the private sector and local communities (Geacu et al., 2012).

An increased surface of protected areas was a priority of Romania's over the accession to the European Union. Thus, a series of decisions were taken by the Romanian Government during 2004-2010 (No. 2151/2004, 1581/2005, 1143/2007, 1066/2010 and 1217/2010) that led to the extension of the number of protected areas. Thus, up to now, Romania has: 998 protected areas of national interest: 79 scientific reserves - I; 13 national parks - II; 230 natural monuments - III; 661 natural reserves - IV; 15 parks - V.

At the international level Romania has: 3 Biosphere Reserves: Danube Delta (1991), Retezat Mountains (1979), Pietrosul Rodnei (1979); 5 Ramsar sites: Danube Delta (1991), Small Wetland of Brăila (2001), The Mureş Meadow (2006), Dumbrăviţa Fishery Complex (2006), Techirghiol Lake (2006); a World Heritage Site: Danube Delta (Geacu et al., 2012).

Natura 2000 is an ecological network of protected areas in the European Union that aims to maintain a favorable conservation status a selection of the most important habitat types and species in Europe. It is the main instrument of European Union for nature conservation in the Member States. Natura 2000 network consists of: *Special Areas of Conservation*, established under the Habitats Directive (Directive 92/43 of 1992 on the conservation of Natural Habitats and of Wild Fauna and Flora) and *Special Protection Areas* - established under the Birds Directive (Directive 79/409 of 1979 on the Conservation of Wild Birds).

In the Romanian legislation the two Directives have been transposed by Law no. 462/2001 (approving the Government Emergency Ordinance no. 236/2000 on the regime of protected natural habitats, wild flora and fauna). Through its high biodiversity value, Romania brings a significant contribution to the European Ecological Network. The declaration and recognition of European Natura 2000 areas in Romania is still an ongoing process having its deadline in 2016.

The establishment of Natura 2000 network in Romania underwent two stages, so far. In the first stage 273 Sites of Community Importance (by Order of Ministry no. 1964/2007) and 108 Special Protection Areas (by Government no. 1284/2007) were declared. In 2011 the network was extended to 408 SCI (39,952 km^2) and 148 SPAs (35,542 km^2) through the Order of Ministry Environment and Forests no. 2.387/2011 and the Government Decision no. 971/2011, respectively. Through these regulations the total area of Natura 2000 areas in Romania reached the 54,067 km^2, which represents 22.68% of the national territory (Bălteanu et al., 2009; Geacu et al., 2012).

The current assessment of terrestrial invasive plant species (ITPS) on some Romanian protected areas considered as case studies, one for each biogeographical region: Alpine (Rodna Mountains National Park and Maramureş Mountains Natural Park), Pannonic (Mureş Floodplain Natural Park), Continetal (Comana Natural Park), Steppic (Măcin Mountains National Park) and Pontic (Danube Delta Biosphere Reserve) (Figure 3.2).

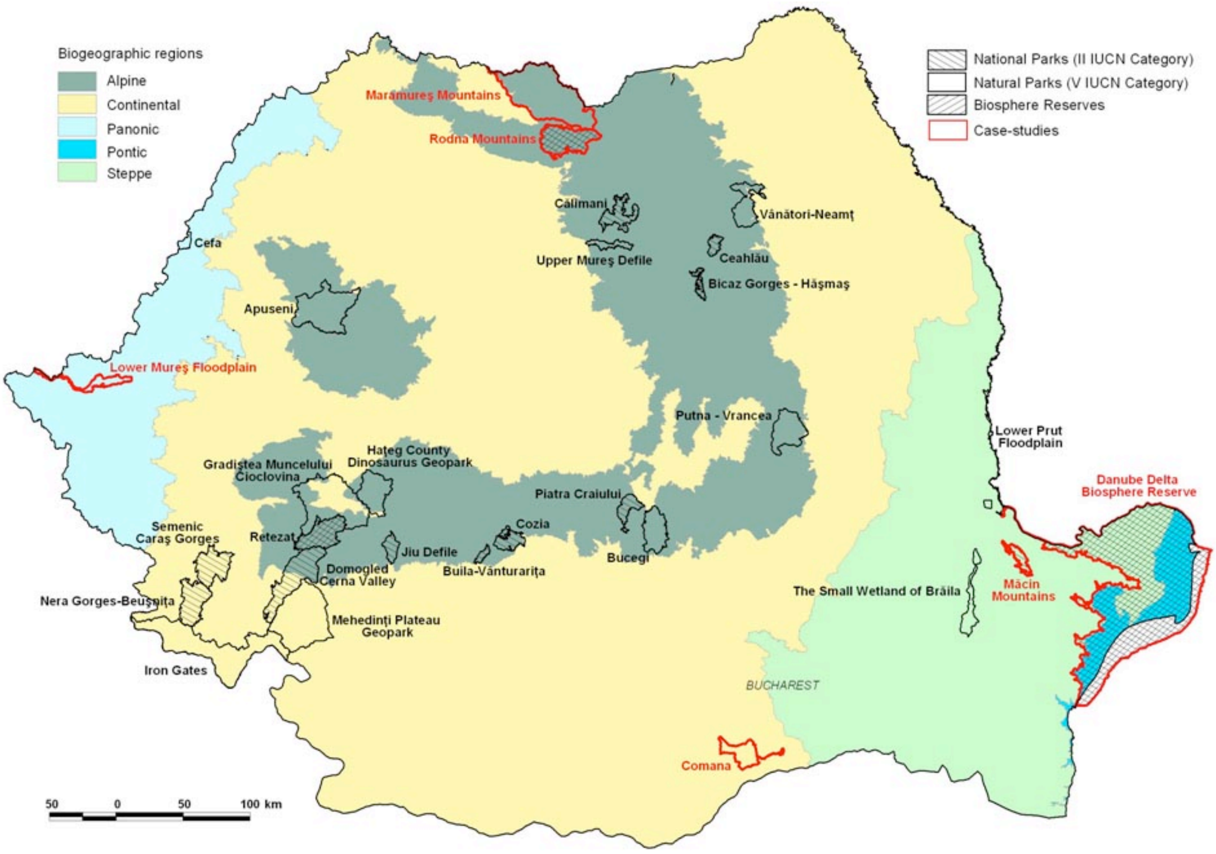


Figure 3.2. Selected case-studies in the Romanian natural protected areas.

3.3. Key environmental driving forces in assessing ITPS (IGAR)

The scientific literature considers some large-scale geographical factors able to explain the role of environmental driving forces in their distribution and spread in some European countries: ***climatic factors*** (mean annual precipitation, mean annual temperature, temperature amplitude between July and January), ***geographical factors*** (latitude, longitude and area) and ***economic factors*** (population density, Gross Domestic Product and roads density) (Lambdon et al., 2008). At a smaller scale, the main environmental drivers responsible for the introduction and spread of the ITPS in Romania are of ***natural and human-induced nature*** (Table 3.1).

Based on the previous approaches, developed mainly as descriptive analyses of each factor involved, the present investigation is aiming to assess the environmental drivers concurrently and integrated into a potential model able to offer both relevant causal rationales and spatial analysis in relation to the species requirements.

The characteristics of natural and human-induced factors can cause a species to invade, persist and grow excessively in one area. To this effect the main environmental factors affecting the dynamics of invasive species in Romania were identified.

Table 3.1. The main environmental driving forces responsible for the introduction and spread of the ITPS in the Romanian protected areas

Major driving forces		Consequent driving forces
NATURAL	**soil**	soil type, texture
	relief characteristics	altitude, slopes exposure, declivity, geomorphic features etc.
	vegetation	dominant vegetation types, fragmentation
	water bodies, wetlands	lakes, rivers, ponds, marches
	climate	air/soil temperature, precipitation, air humidity, wind, climate change signals
	extreme events	flooding, wind and snow felling, heavy rains
HUMAN INDUCED	**planting invasive species**	for ornamental/ recreation, forestry purposes
	agricultural practices	crop type, land abandonment, excessive fertilizers
	forest exploitation	deforestation/forest fragmentation, forest infrastructure
	grazing	pastures and land degradation
	urban development	waste deposits, transport network (roads, railways etc.), building sites

Source: Dumitraşcu et al., 2010 (adapted and restructured)

Relief. One of the main natural factors influencing invasive species is relief. With its features and the morphological variety, relief influences the development and dissemination of invasive species being either favorable or restrictive factors for their dynamics. Morphography and relief morphometry (hypsometry, fragmentation, and gradient slopes) determine the differentiation between other natural factors (lithology, soils, vegetation, hydrography, climate, etc.), thus creating a specific natural potential specific to different types of invasive species. For example, the slopes' exposure influences the development of *Amorpha fruticosa* or *Ailanthus altissima* mainly on the southern, south-eastern and south-western slopes because of these species' preference for light.

Lithology and soils. The physical and chemical components of the soil are a favorable or unfavorable factor in the development and dissemination of invasive species. It is known that many of these are true indicators of litho-pedological features in a given geographical area. In this regard, acid soils favor the development of abundant blueberries, soils rich in nitrogen favor *Rumex alpinus*, the humid soils favor the amorphous, and degraded soils are good for seabuckthorn etc. Also, some studies showed the exclusive preference of the species *Amorpha fruticosa* in the Comana Natural Park for Luvisoils (a typical reddish-brown sub-type), with a loam-clayish texture, rich in nitrogen, potassium and phosphorus and of the species *Ailanthus altissima* in the Rodna Mountains National Park for Cambisoils having a sandy to clayish texture (Dumitraşcu et al., 2010).

Climate peculiarities influence differently the presence and dynamics of invasive species, through the characteristics of air and soil's thermal regime, through the hygrometric regime, the rainfall and wind patterns. However, in the context today's climate change (increased air temperature, low rainfall and increased frequency and intensity of extreme hydro-meteorological phenomena), emphasized especially in the latter part of the twentieth century, conditions favorable/unfavorable to the occurrence and dissemination of invasive species are created (Dragotă et al., 2012).

Areas affected by storms. The *Ailanthus altissima* species prefers degraded forest ecosystems affected by extreme phenomena (wind/snowfall).

Vegetation. The diversity of plant formations makes adaptation and spatial distribution of invasive species dependent according to the type of plant associations and their current state. Changes brought by human activities to the distribution, structure and composition of plant formations can sometimes encourage the growth of invasive species which compete with native formations.

Hydrography. Recent studies have shown that wetland ecosystems are most likely the most susceptible ones because of regular hydrological imbalances (floods) that destroy riparian vegetation causing niches that favor the penetration of invasive species. Thus, rivers act as natural vectors and dispersing agents facilitating the spread of invasive species (Fenesi et al., 2009). For example, some species such as *Echinocystis lobata*, *Helianthus tuberosus*, *Solidago canadensis*, *Solidago gigantea subsp. serotina*. and *Rudbeckia laciniata* which were originally cultivated, have currently become widespread in areas of Transylvania, Banat and Crisana where they have invaded local plant communities, while other invasive species (*Acer negundo, Ailanthus altissima, Aster lanceolatus, Ambrosia artemisiifolia, Parthenocissus inserta*) only occur sparsely (Anastasiu et al., 2008).

Land use/land cover have a significant influence on the distribution and spread of invasive species. For example, for the *Amorpha fruticosa* arable land is a favorable vector. Studies in the United States, China and Korea on phytoremediation have shown that high fertilization, mainly the organic kind, has improved the growth rate of the species (Li 2006; Seo et al., 2008; Marian et al., 2010; Xiang 2011); ***meadows and bushes*** - recent studies have shown that the *Amorpha* has improved its invasive potential with regards to these land use categories, with negative effects on natural vegetation (Sărăţeanu, 2010). Regarding the *Ailanthus altissima* species field research led to the identification of well-developed individuals in areas covered by ***pastures*** (Dumitraşcu et al., 2011a; Dumitraşcu et al., 2011b). Although ***wetlands*** appear to be more susceptible to being invaded than other ecosystems, acting as natural factors and dispersing agents (Fenes et al., 2009), it proved to be quite restrictive for this species, since it preferred rather temporary courses of rivers and eutrophic lakes because of the organic matter enrichment of soils; ***forests*** - may represent a limiting factor especially for *Amorpha fruticosa* etc.

Agricultural practices can influence the dynamics of invasive species through various vectors of occurrence and dissemination of new species: type of crops, land fragmentation, agricultural pollution, land abandonment, etc. They may initially appear as pest species that after several years will expand, completely invading the initial agro-ecosystems, changing its use (e.g. into a secondary grassland or climaxic forest). The main invasive species in agricultural ecosystems are *Cirsium arvense, Galinsoga parviflora, Conium maculatum, Xanthium italicum, Prunus spinosa*.

Forest exploitation. The development and diversification of human activities have led to putting high pressure on forests. In most cases, the tree felling is not followed by reforestation, causing fragmentation of forests, land degradation and the endangerment of species of plants and animals whose habitat is the forest. Thus, these actions encourage the penetration and expansion of invasive species by overtaking the affected areas and competing with existing native species.

Intensive grazing or overgrazing has led to degradation and hence to the decrease in biological diversity and productivity of grasslands. For example, the expansion of grazing within subalpine meadows led to a decrease in mountain pine (*Pinus mugo*) the second half of the past century from the upper woodlands in all the Romanian Carpathians and thus accelerating erosion by grazing and the introduction of new species with invasive traits (*Rumex alpinus, Urtica dioica, Pteridium aquilinum*). Thus, irrational grazing contributes to the change in the floristic composition of grasslands, eliminating certain plant associations and favoring the appearance of others due to changes in the physical and chemical conditions of the soil.

Introducing invasive species. Another way of introducing invasive plant species in Romania is by humans for ornamental/recreational, forestry purposes or for the ecological restoration of degraded lands. Most times, the development of these species got out of control, they were naturalized and have increased excessively, becoming locally abundant and entering into competition with other native species. Thus, of the total of 435 identified as being of foreign origin in the Romanian flora, 96 were introduced deliberately by humans for ornamental purposes. The most aggressive ornamental neophytes seem to be the *Acer negundo, Ailanthus altissima and Impatiens glandulifera*. These species require special control measures so that their impact on native plant formations are limited (Anastasiu et al., 2008).

Mining activities results in a modification of the physical, chemical and biological environmental factors by storing mine tailings or mine water thus favoring the introduction of invasive species (*Erigeron annuus ssp annuus, Conyza canadensis, Impatiens glandulifera, Helianthus tuberosus, Echinocystis lobata, Xanthium italicum* etc.) that may constitute a threat to local biodiversity. Also penetration of invasive species in areas affected by mining activities can be achieved through re-naturalization actions on affected lands using species that can grow excessively after entering into competition with native species.

Urban expansion can cause the appearance and spread of invasive species especially in areas adjacent to building sites, to ways of communication and so on, especially by removing the primary vegetation and developing ruderal vegetation. Also, soil degradation in these areas by altering their physical and chemical characteristics causes the appearance of species adapted to the new environmental conditions with a different pH and and different chemical compounds as opposed to the original ones (*e.g. Urtica dioica, Atriplex tatarica, Sambucus ebulus, Conium maculatum*).

The transportation network is another key factor both as a source of pollution (Li 2006; Seo et al., 2008, Marian et al., 2010; Xiang 2011) as well as a way of introduction/dissemination of invasive species. For example, in the Comana Natural Park ***railways*** and ***major roads*** show an excellent development potential for *Amorpha fruticosa*, especially along non-electrified routes, while in Rodna Mountains National Park ***forest roads*** are potential dissemination areas for *Ailanthus altissima* (Dumitraşcu et al., 2011c).

3.3.1. Climatic potential and key meteorological drivers for the dynamics of ITPS in Romanian protected areas (IGAR + DDNI)

Because of their highly competitive character, the ITPS could alter the composition of local ecosystems, changing their structure and function, and ultimately leading to environmental degradation. All these changes, to which ecosystems are highly sensitive, are often exacerbated by the dynamics of the key climatic drivers (air/soil temperature, precipitation, winds etc.). Therefore, changes in weather and climate can also have both individual and cumulative effects on ecosystems that can further facilitate the expansion and abundance of invasive plant species (Taush 2008; Shi et al., 2010).

The broad ratification of the Convention of Biodiversity (Rio de Janeiro, 1992) enhanced the support of different prevention and control measures for the invasive alien species. Although Romania has approved the Convention by means of law 58/1994, until now no important steps were made, especially in terms of implementation of article 8, with respect to alien invasive species (Dumitraşcu et al., 2010).

Currently, the invasive flora of Romania includes over 400 species (13.87% of the Romanian flora) belonging to 82 families, out of which 88.27% are neophytes and 11.73% archaeophytes (Anastasiu and Negrean, 2005; Sîrbu and Oprea, 2008). According to the third National Report of Biological Diversity Convention, six of the invasive alien species are tree species (*Acer negundo, Ailanthus altisima, Amopha fruticosa, Cytisus scoparius, Fraxinus americana,* and *Fraxinus pennsylvanica*). Over the recent years, new alien species have continuously been reported (Sîrbu & Oprea, 2008; Dumitraşcu et al., 2010).

Most Romanian taxa belongs to families which invade habitually temperate climate zones: Asteraceceae (61 taxa), Brassicaceae (38 taxa), Poaceae (30 taxa). Numerous families, like Orchidaceae do not have alien representative in our flora, while others, like Amaranthaceae have almost exclusively alien representatives (Anastasiu & Negrean, 2005). When discussing the most aggressive ITPS in the Romanian protected areas, the following range first: (Doroftei et al., 2005; Dumitraşcu et al., 2010) (Table 3.2).

Table 3.2. The most important ITPS in the Romanian protected areas

ITPS	Native	Family	Height (m)
Elaeagnus angustifolia	W. Asia	*Elaeagnaceae*	3-6
Acer negundo	N.Am.	*Aceraceae*	10-15
Ailanthus altissima	Asia	*Simaroubaceae*	7-10
Amorpha fruticosa	W.N.Am.	*Fabaceae*	2-4
Robinia pseudoacacia	N.Am.	*Fabaceae*	10+
Lycium barbarum	Asia	*Solanaceae*	1-2.5
Fraxinus pennsylvanica	N. Am	*Oleaceae*	15+
Morus alba	Asia	*Moraceae*	10-15
Gleditsia triacanthos	E.N.Am.	*Caesalpiniaceae*	6-8
Lonicera japonica	E. Asia	*Caprifoliaceae*	2-4

Protected natural areas in Romania cover 1,798,782 hectares, that is, 7.55% of the national territory. According to the Romanian regulations 958 protected areas were established: 13 national parks (316,047.3 h), 14 natural parks

(827,799.6 ha) out of which 2 geoparks (206.978,3 ha), 3 biosphere reserves, 54 scientific reserves (100,224 ha), 240 monuments of nature (2,213.3 ha), 626 nature reserves (161,838.3 ha) (Bălteanu et al., 2009).

As an expression of both geographical diversity and local evolution of human-environment relations, the Romanian protected areas mirrors *unique and rich natural landscapes* whose main traits are put into risk by the ITPS with severe consequences on the native habitats.

Methods and data. In assessing the climatic potential in relation to the distribution and spread of ITPS the authors used and processed the meteorological data of the most relevant weather stations from the major Romanian protected areas. The weather stations were selected based on their significance in terms of main environmental features (climatic, morphological, elevation etc.) which complies with the World Meteorological Organization requirements, in order to provide accurate data (Figure 3.3).

Therefore, annual, monthly and daily extreme climatic values (temperature, precipitations, wind) from all the relevant meteorological stations for the Romanian protected areas for the 1961-2007 time frame were processed. Based on these climatic data, the climatic potential characteristic to the protected areas responsible for the development of the ITPS according to the climatic requirements and biological features (Table 3.3 and Table 3.4) were analyzed (air and soil temperature, precipitations mainly during the warm semester of the year, relative air humidity and wind relevant parameters etc.) (Dragotă et al., 2011).

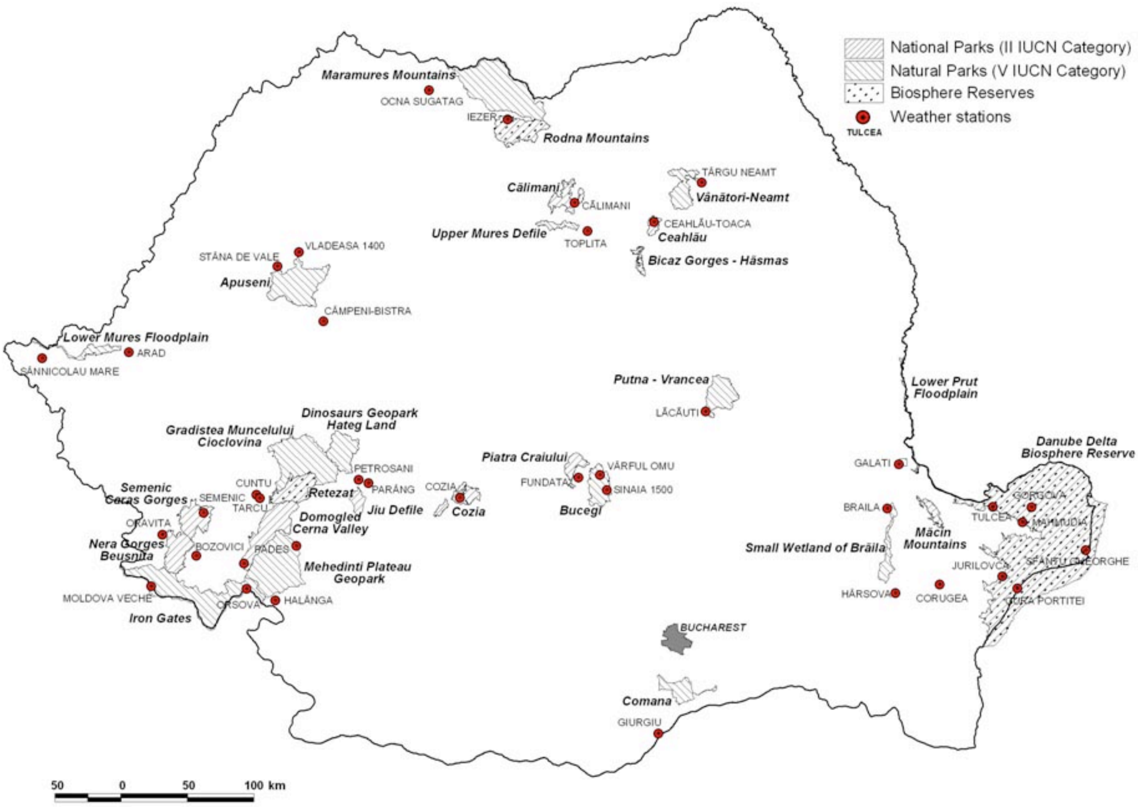


Figure 3.3. Major natural protected areas in Romania and the related relevant weather stations.

Table 3.3. The main biological and spread conditions of ITPS (I)

ITPS	Growth habitat/rate	Active growth period	Vegetative spread rate
Elaeagnus angustifolia	shrub-tree/fast	spring& summer	None
Acer negundo	tree/fast	spring & summer	slow
Ailanthus altissima	tree/fast	spring& summer	rapid
Amorpha fruticosa	shrub/fast	spring & summer	none
Robinia pseudoacacia	tree/fast	spring	moderate
Lycium barbarum	shrub/fast	early summer	fast
Fraxinus pennsylvanica	tree/fast	spring & summer	none
Morus alba	tree,shrub/moderate	spring & summer	none
Gleditsia triacanthos	tree-shrub/fast	spring & summer	none
Lonicera japonica	vine/fast	spring & summer	rapid

Table 3.4. The main biological and spread conditions of ITPS (II)

ITPS	Dispersal	Propagation	Fruit/Seed abundance
Elaeagnus angustifolia	Zoochoric	seed & vegetative	high
Acer negundo	Zoochoric	seed	high
Ailanthus altissima	hydrochoric & zoochoric	seed & vegetative	high
Amorpha fruticosa	hydrochoric & zoochoric	seed & vegetative	high
Robinia pseudoacacia	zoochoric	seed & vegetative	medium
Lycium barbarum	zoochoric	seed & vegetative	high
Fraxinus pennsylvanica	anemochoric	seed & resprout	high
Morus alba	zoochoric	seed & vegetative	high
Gleditsia triacanthos	zoochoric	seed & resprout	high
Lonicera japonica	-	seed & vegetative	low

Additionally, based on a selection of most aggressive ITPS in the Romanian protected areas the authors tried to draw up each one's niche profile in terms of climatic and topoclimatic requirements related to thermal, pluvial and eolian factors' dynamics (Table 3.5).

Ultimately, based on ITPS climatic profile/requirements and each protected area climatic features the key meteorological drivers responsible for the dynamics of ITPS in the Romanian protected areas were outlined.

Changing climatic conditions influence three essential elements of invasion: *the source location, the pathway* and *the destination* (Dangles et al., 2008). Also, it could determine *shifting species habitats* and *species migration* (to higher/lower elevations, to more friendly habitats etc.). The native species that will not be able to migrate can disappear. Some studies have shown that short-term changing climatic conditions may facilitate the long-term establishment of ITPS. Therefore, species that tolerate a wide range of climatic conditions could become the most successful invaders (Taush, 2008). For example, precipitation variations could cause water-loving/resistant species to outcompete one another. From the perspective of ITPS's biogeographical origin, rising temperatures would allow the spread northward of some Mediterranean-origin species and enhance winter survival of some other organisms. Decreasing temperature could determine the propagation southward of some Alpine-origin species.

Table 5. The main climatic requirements of ITPS

ITPS	Frost free days min.	Moisture/drought resistance	Shade tolerance
Elaeagnus angustifolia	100	high	intolerant
Acer negundo	100	high	tolerant
Ailanthus altissima	150	high	intolerant
Amorpha fruticosa	100	high	intolerant
Robinia pseudoacacia	90	high	intolerant
Lycium barbarum	100	high	intolerant
Fraxinus pennsylvanica	120	medium	facultative
Morus alba	130	medium	facultative
Gleditsia triacanthos	180	high	intolerant
Lonicera japonica	130	medium	tolerant

The great diversity of geographical conditions in the Romanian protected areas point to an uneven distribution of the **annual mean air temperatures**, generally ranging between 11-12°C in the south of the Romanian Plain, along the Danube Valley, in the southern and western parts of the Banat region and on the Black Sea coast (Comana Natural Park, Iron Gates Natural Park, Danube Delta Biosphere Reserve) and -2.7 - 0°C … on the highest Carpathian summits (Bucegi Natural Park, Retezat Biosphere Reserve, Rodna Mountains National Park etc.). In the hilly and plateau regions temperatures fall under 10°C (Vânători-Neamţ Natural Park). The mean annual amplitudes of this parameter could reach the highest values in the southern and south-eastern areas (25-26°C).

Mean monthly temperatures reveal the thermal contrasts between both extreme seasons and between the months of the analyzed years (January and July). Therefore, in January the values ranges between 0°C (Danube Delta Biosphere Reserve), - 2… - 3°C in the south, south-eastern and south-western protected areas and -11°C in the mountain ones. In July, the highest temperatures, over 21-23°C, are registered in the plain regions from the south of Romania as well as on the coastal zone and the lowest on the high Carpathian peaks, when the air temperature drops below 6°C.

Non-periodic variations due to fluctuations in general atmospheric circulation highlight very cold (1942, 1947, 1963) or very warm (1936, 1948, 2000, 2007) years. The same thermal differences at all time scales occur at the local level between the elementary topoclimates of each protected area involved (forests, fields, valley corridors with terraces, wetlands etc.).

In the distribution of thermal parameters the *mean daily maximum temperatures* are noteworthy when it comes to assessing the impact of temperature on ITPS. They could exceed 25 °C in the plain and low hills protected areas from the southern, eastern and western parts of Romanian (Danube Delta Biosphere Reserve, Comana and Lower Mureş Floodplain Natural Parks etc.) but also drop below 10 in the high mountain regions protected areas (Rodna Mountains, Călimani and Retezat National Parks) (Figure 3.4).

In regard to the *frost phenomenon*, especially the *annual frost free interval* (with minimum air and soil level temperature of ≥0°C) which has major implications for the development/restraining of vegetal phenophases. In the Danube Delta Biosphere Reserve, Comana and Mureş Floodplain Natural Parks the multi-annual average of this parameter varies between 200 and 225 days while in the mountain protected areas registers less than 150 days.

Soil temperature which converts the soil surface into the main source of heat is also significant, thus having a strong impact on the vegetative cycle. The variation of soil temperature parameters in the Romanian protected areas rages in mean annual values between 12-13°C (Low Mureş Floodplain and Comana Natural Parks, Danube Delta Biosphere Reserve etc.) and below 7°C in the mountain protected areas. Thus, in the protected areas from Southern Romania, the *maximum annual average* of nearly 28ºC is favoured by the highest values of solar radiation, the texture of dark soils formed under steppe and forest steppe conditions, the high degree of vegetal coverage etc. The soil temperatures reached maximum values of over 65ºC in the plain areas from southern and south-eastern Romania (67.4 ºC/31.07.1985 in the Comana Natural Park and 65.0/3.08.1966 in the Măcin Mountains National Park) (Dragotă et al., 2011).

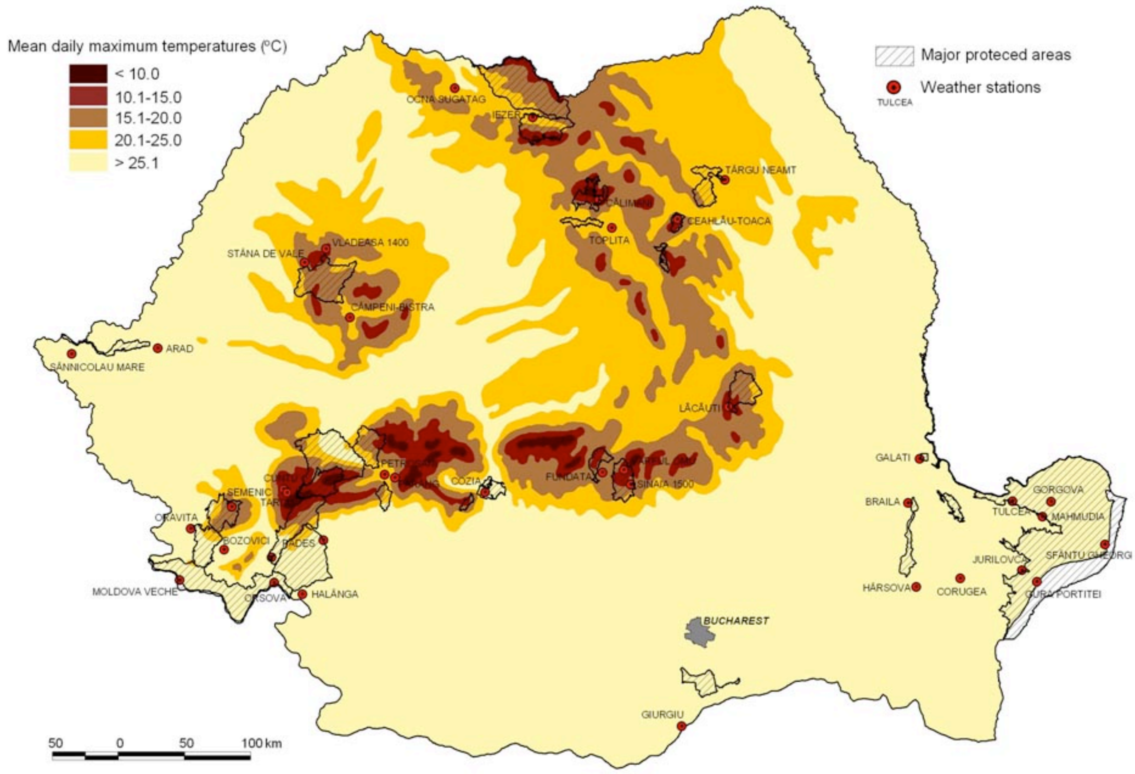


Figure 3.4. Mean daily maximum temperatures (July) (processed after Sandu et al., 2010)

Table 3.6. Relevant extreme summer/winter-related temperature parameters in some selected protected areas (annual average)

Protected area	Tropical days/nights	Frosty days/nights
Danube Delta Biosphere Reserve	17.9 / 10.5	83.6 / 7.6
Măcin Mountains National Park	21.3 / 3.7	102.3 / 11.4
Comana Natural Park	49.6 / 5.9	96.8 / 11.4
Lower Mureş Floodplain Natural Park	31.5 / 2.6	94.5 / 11.3
Vânători Neamţ Natural Park	6.7 / 5.9	120.7 / 22.9
Retezat National Park	0.0 / 0.0	219.6 / 68.6
Rodna Mountains National Park	0.0 / 0.0	198.0 / 61.3

The summer and winter days with extreme temperatures influences the vegetative cycle of ITPS through their frequency and intensity. In annual average, these parameters reveal high differences induced by regional and local characteristics in terms of altitude, topoclimatic features, vegetation coverage etc. (Table 3.6).

The content of vapours in the atmosphere, mainly depending on to the physical features of air masses dynamics, temperature and the characteristics of the active surface (large water and vegetation-covered surfaces), increase the level of air humidity, while being permanent sources of evaporation and evapotranspiration. The air saturation with water vapours - **relative air humidity (RU)** displays in the Danube Delta and mountain areas mean annual values of over 80%, higher during winter, when in December exceeds 90% in the plain protected areas.

The average annual frequency of "dry days" (where RU ≤ 30%) registers the highest frequencies (over 20 days) during the warm semester of the year in the Comana and Iron Gates Natural Parks. The number of "humid days" (RU ≥ 80% at 1 PM) displays a maximum frequency during the cold semester of the year in the mountain protected areas (over 250 days) and Danube Delta Biosphere Reserve (nearly 150 days).

In relation to some of the main ITPS biological parameters (growth rate, vegetative spread rate, fruit/seed abundance etc.), these parameters are very significant when it comes to plant's distribution and spread.

The key environmental features of the Romanian protected areas in relation to the main pressure centres lead to a different distribution of **precipitation** amounts alternating on an annual regime between < 300 mm (Danube Delta Biosphere Reserve) and > 1 400 mm (Apuseni Mountains Natural Park).

The largest share of seasonal precipitation amounts is registered during the warm semester, when most of ITPS vegetative cycle is at its highest peak (Figure 3.5). The values can reach between 154.2 mm (Danube Delta Biosphere Reserve) and 729.3 mm (Apuseni Mountains Natural Park), June being the richest month and February and October the poorest (Dragotă, 2006).

These may affect the optimal development of the vegetative cycle during the active growth period and may influence the dissemination of ITPS in the Romanian protected areas, especially when it comes to hydrocoric seed propagation for the species having high seed abundance index.

The pluvial characteristic of the 1961-2007 time span, as compared to the previous one (before 1961), shows annual fluctuations in precipitation amounts as deficits (1961, 1983, 1986, 1990, 1993, 1994, 2000, 2007) and excess rainfall (1969, 1970, 1975, 1991, 1992, 1997, 2005). Coupled with warmer periods, these pluvial extremes trigger negative impacts on the growing season of humidity/drought-loving ITPS *Amorpha fruticosa, Fraxinus pennsylvanica, Acer negundo, Robinia pseudoacacia and Ailanthus altissima* etc.).

The **wind** by means of speed and frequency parameters acts as a vector for the dissemination of ITPS depending on their main biological features (propagation and dispersal type etc.). For example, the predominant wind direction in Carpathian protected areas (Apuseni and Grădiştea Muncelului-Cioclovina Natural Parks etc.) is westward. In the eastern and south-eastern Romania the north-west and east directions are found (Vânători-Neamţ Natural Park and Comana Natural Park, respectively). In the Danube Delta Biosphere Reserve the northern direction prevails.

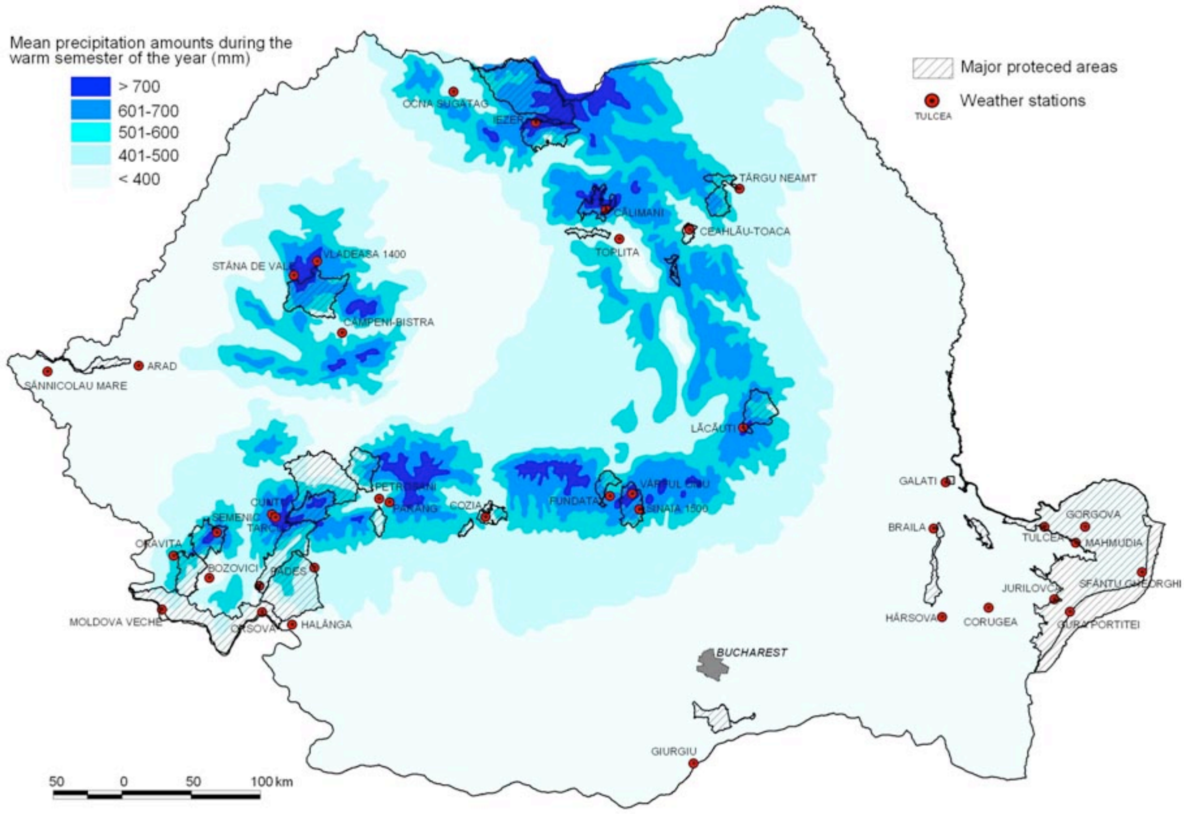


Figure 3.5. Mean annual precipitation amounts during the warm semester of the year (processed after Dragotă 2006)

Depending on the local factors (aspect of slopes and orientation etc.) other directions could develop (Figure 3.6).

In general, the *average speed no matter the direction* ranges between 2 - 3 m/sec in the Comana Natural Park, 4-6 m/s in the Danube Delta Biosphere Reserve and Măcin Mountains National Park and 8 - 10 m/s in the high mountain protected areas.

Dangerous climatic phenomena in terms of high intensity and frequency contribute differently to providing favourable/unfavourable conditions for the development of ITPS phenonophases, thus having a mechanical effect on plants (e.g. frost and hoarfrost, glazed frost, heavy rainfall, strong winds etc.). Among all the analysed climatic parameters and meteorological elements involved in the dynamics of ITPS in the Romanian protected areas, some of them range first when discussing their action as drivers in the distribution and spread of these plant species (Table 3.7). Thus, early or late frosts and hoarfrosts, aridity and drought, heavy rainfall, hail storms, strong winds, blizzards, etc. through their physiological and mechanical effects distort, break or cause temporary imbalances in the natural evolution of vegetation.

Discussions. ITPS can be both the result of global changes and the drivers of change. They may be harmful to crops, industries, the environment and public health. Ecologically, ITPS are very problematic for biodiversity conservation leading to native species extinction, thus determining high conservation costs.

Relating local environmental features (slope, soil, water etc.) and the climatic parameters of meteorological elements for the achievement of optimum thermal, hydric and aeolian conditions for the development of ITPS (in terms of specific bioclimatic requirements) have a key role in their distribution and spread.

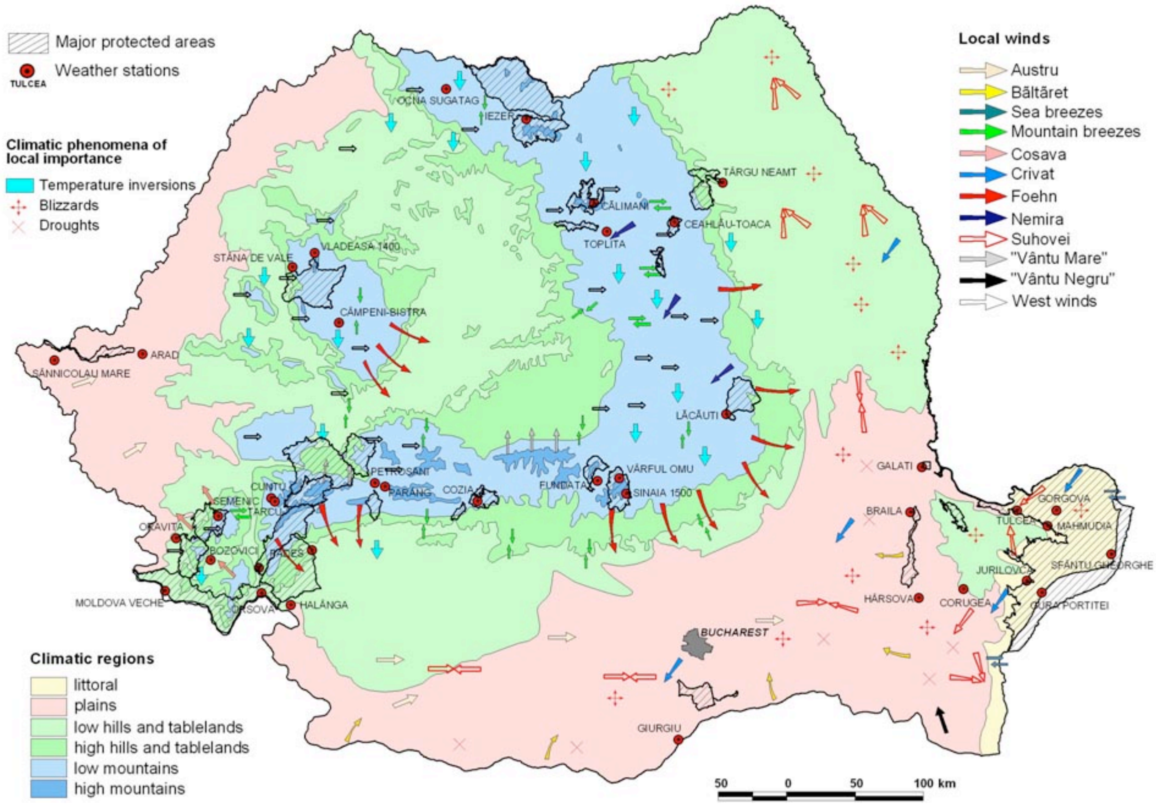


Figure 3.6. Main wind characteristics and climatic regions (processed after Bogdan & Frumuşelu, 2002)

Table 3.7. Key meteorological drivers for the dynamics of ITPS in the Romanian protected areas

<table>
<tr><th>ITPS</th><th colspan="4">Key meteorological drivers</th></tr>
<tr><td rowspan="7">Thermophilic</td><td colspan="2">Mean daily maximum temperatures</td><td rowspan="11">Strong winds (≥ 16 m/s)</td><td rowspan="11">Identifying the hazardous climatic phenomena according to exceeding relevant steps (positive/ negative deviation against the mean multi-annual values – 2, 3 σ/min)</td></tr>
<tr><td colspan="2">Heat waves (> 3 consecutive days)</td></tr>
<tr><td rowspan="3">Summer days with different characteristic temperatures</td><td>mountain areas – summer and tropical days</td></tr>
<tr><td>hills/plateaus – summer and tropical days</td></tr>
<tr><td>plain areas – tropical days, tropical nights</td></tr>
<tr><td colspan="2">Water table contribution (relevant indexes and indicators)</td></tr>
<tr><td colspan="2">Potential evapotranspiration</td></tr>
<tr><td></td><td colspan="2">Climatic water deficit</td></tr>
<tr><td rowspan="2">Hygrophilic</td><td colspan="2">The number of "humid days" (RU ≥80% at 1 PM)</td></tr>
<tr><td colspan="2">The number of "dry days" (RU ≤30% at one of the terms of observation)</td></tr>
<tr><td>Hydrophilic</td><td colspan="2">Days with precipitation amounts ≥ 5.0 mm (coupled with groundwater input)</td></tr>
</table>

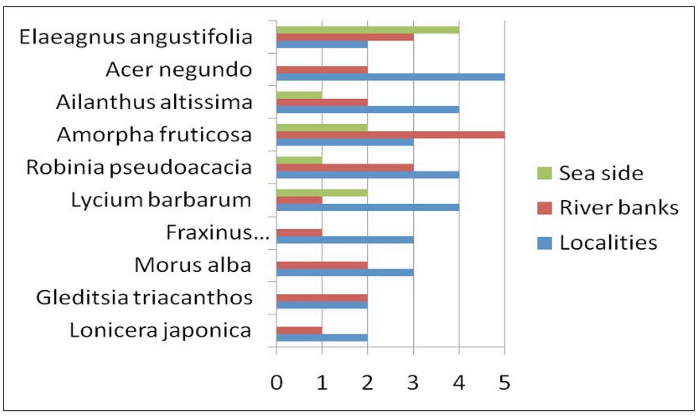
All these general and local climatic features provide the favourable framework for the optimal development of ITPS growing in the Romanian protected areas, concurrently indicating the expansion/reduction probability of areas they occupy, thus defining the climatic stress elements specific for each protected area. Therefore, preventing the spread of invasive species into more susceptible environments requires an awareness of the types of species that pose a threat to a particular ecosystem.

3.3.2. Integrating key climatic and meteorological drivers in assessing the dynamics of invasive terrestrial plant species in Danube Delta Biosphere Reserve (IGAR + DDNI)

Danube Delta Biosphere Reserve, both II IUCN category and Natura 2000 site (SCI and SPA). The study-area enfolds the delta territory which develops between the three arms of the Danube River, the Danube Floodplain downstream of the town of Tulcea, the Black Sea waters up to the -20 m isobath and the Razim-Sinoie Lake Complex. Therefore, over 90% of its surface, which totalises 5,800 km^2, is covered by lakes, ponds and swamps with reed and club rush. It is the place where 325 bird species use to nest or pass through, some of them of European or global interest (Bălteanu el al., 2006; Bălteanu el al., 2009).

The historical overview on preserving this ecosystem of international importance dates back to the first have of the 20s century when two nature reserves were declared: *Letea Forest* in 1930 and *Roşca-Buhaiova-Hrecişca* in 1940. After the Romanian Academy's Commission for the Protection of the Monuments of Nature being established in 1950, the protected areas in the Danube Delta have increased in surface and number (Gâştescu et al., 2008). At the Fourth International Session of the Man-Biosphere Programme (Paris, November 19–28, 1979) Roşca–Letea (the Danube Delta) was proposed to be declared biosphere reserve (accepted on January 10, 1980). Due to the harmonious interaction between man and wildlife, Danube Delta won the Biosphere Reserve status in 1990 and included on the UNESCO's Heritage List and, in 1991, on the List of Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Bălteanu el al., 2006). In 1998, was designated part of a transboundary Biosphere Reserve with Dunaisky in Ukraine. Besides, Danube Delta Biosphere Reserve is also recognised as the largest continuous marshland and the second-largest and best preserved deltas in Europe (UNEP/WCMC, 2011).

Due to the particular environmental features of the study-area, mainly in terms of wide extension of wetlands known to be more susceptible to invasion than other ecosystems (Fenesi et al., 2009), and the intensification of human-induced impacts on native ecosystems, the study area is more exposed to the penetration and spreading of different invasive terrestrial plant species (Zedler & Kercher, 2004). Depending on species preference for the main types of natural or human-modified ecosystems (sea side, river banks or localities) and according to their abundance/dominance scale, *Acer negundo, Ailanthus altisima, Amopha fruticosa, Elaeagnus angustifolia, Lycium barbarum, Robinia pseudoacacia* ranks first among the most widespread ITPS in the Danube Delta Biosphere Reserve (Doroftei at al. 2005; Doroftei 2009a and 2009b) (Figure 3.7 a, b).



a

Abundance-Dominance Scale	Average percent of species coverage
5	87.5%
4	62.5%
3	37.5%
2	17.5%
1	5.0 %

b

Figure 3.7. The distribution of invasive ligneous plant species in the Danube Delta Biosphere Reserve (a) according to the abundance/dominance scale (b) (Doroftei, 2009b)

As a consequence, due to the interaction between the main environmental features and the key meteorological parameters and extremes, Danube Delta Biosphere Reserve holds a particular place, displaying several climate features with impact on ITPS:

- the highest values of solar radiation energy flows and sunshine duration related to the anticyclonic dominance and the persistence of hot air advections for several months;
- the uppermost air temperature values in Romania;
- the high frequency of processes related to air downwarding from the lower atmosphere which favours the persistence of clear sky, especially during summer and at noontime;
- the lowest mean multiannual precipitation amounts;
- the highest precipitation amounts fallen in short intervals (24 and 48 hours) due to extreme weather events triggered by the high frequency of thermoconductive processes;
- extended periods of dryness and drought phenomena, thus ranking the area among the first three in the country in terms of frequency, duration and intensity;
- high wind speeds and frequencies, thus bringing about the highest energy wind power in the country;
- elevated evaporation and evapotranspiraton intensities;
- high degree of vulnerability to strong winds (≥16m/s);
- increased frequency and intensity of dangerous climatic events (heavy rains, fog, blizzards etc.).

Methodology and data. The complex assessment of the key climatic and meteorological drivers in relation to the dynamics of ITPS in the Danube Delta Biosphere Reserve had as main step the selection of the most aggressive specie in the study area relying on cross-reference bibliographical literature (biological and geographical) as well as on field surveys. Therefore, an assemblage of top ten most aggressive ITPS were selected *Elaeagnus angustifolia, Acer negundo Ailanthus altissima Amorpha fruticosa Robinia pseudoacacia Lycium barbarum Fraxinus pennsylvanica Morus alba Gleditsia triacanthos Lonicera japonica*.

Furthermore, the authors used and processed the meteorological data from the most relevant weather stations in the study-area: *Tulcea, Gorgova, Sf. Gheorghe, Jurilovca* and *Gura Portiţei.* Due to the short-term weather records, Gura Portiţei was used only as support station (Figure 3.8).

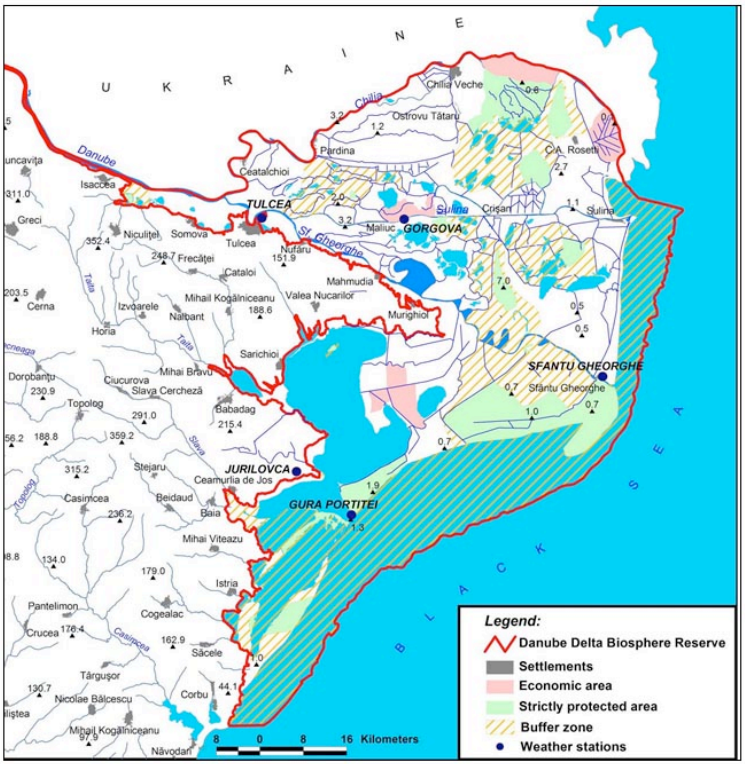


Figure 3.8. Danube Delta Biosphere Reserve

The selection of weather stations was based on their significance in terms of main environmental features (climatic, morphological, elevation etc.) which complies with the World Meteorological Organization requirements, in order to provide accurate data.

Therefore, annual, monthly and daily extreme climatic values (temperature, precipitations, wind) from all the above mentioned meteorological stations for the 1961…2007 time frame were processed. Based on these data, the relationship between the climatic particularities of the Danube Delta Biosphere Reserve and the requirements and biological features of ITPS were analyzed (air and soil temperature, precipitations mainly during the warm semester of the year, relative air humidity and wind relevant parameters etc.). Additionally, based on a selection of most aggressive ITPS, the authors tried to draw up each one's niche profile in terms of climatic and topoclimatic requirements related to thermal, pluvial and eolian factors' dynamics. Ultimately, based on ITPS climatic profile/requirements and Danube Delta Biosphere Reserve climatic features, the key meteorological drivers responsible for the dynamics of ITPS were outlined (Dragotă et al., 2012).

In relation to some of the main ITPS biological parameters (growth rate, vegetative spread rate, fruit/seed abundance etc.), the most relevant meteo-climatic drivers in assessing specie's distribution and spread were outlined.

The key climatic and meteorological drivers in assessing the dynamics of invasive terrestrial plant species in Danube Delta Biosphere Reserve. Changing climatic conditions influence three essential elements of invasion: *the source location, the pathway* and *the destination* (Dangles et al., 2008). Also, it could determine *shifting species habitats* and *species migration* (to higher/lower elevations, to more friendly habitats etc.). The native species that will not be able to migrate can disappear. Some studies have shown that short-term changing climatic conditions may facilitate the long-term establishment of ITPS. Therefore, species that tolerate a wide range of climatic conditions could become the most successful invaders (Taush, 2008). For example, precipitation variations could cause water-loving/resistant species to outcompete one another. From the perspective of ITPS's biogeographical origin, rising temperatures would allow the spread northward of some Mediterranean-origin species and enhance winter survival of some other organisms. Decreasing temperature could determine the propagation southward of some Alpine-origin species. Assessing the relationship between key meteo-climatic drivers and the dynamics of ITPS in the Danube Delta Biosphere Reserve is highly important, especially when considering the most favourable climatic potential of the study-area coupled with the variety of environmental vectors able to stream their distribution and spread. Therefore, the most important meteo-climatic parameters that might influence ITPS's dynamics selected for the current research are related to: temperature, precipitation, relative humidity, wind and dangerous climatic phenomena.

Temperature ranks among the key restrictive ecological drivers in the development of plants. All biophysical and biochemical processes of plants (water, gas and minerals absorption and circulation, respiration, photosynthesis, etc.), growth and development processes are influenced, if not restricted by air and soil temperature. Therefore, in general, it is a limiting factor in plants' distribution, through delineating areas of favourability, categorized by specific mean and maximum thermal thresholds (biological thresholds) specific for the growing season. In the temperate climate, most plant species begin their growing season at temperatures of about 5 ºC, intensifying at 30-35 ºC.

At temperatures greater than 35 ºC, plants' growth weakens significantly, completely ceasing at 40 ºC. Assimilation, dissimilation and breathing processes are also correlated with air temperature shifts. For instance, chlorophyll assimilation is very low at temperatures of 1-3 °C, increasing as temperature rises up to 30-35 °C and decreasing significantly to values of 50 °C at soil level (Neacşa and Berbecel, 1979). The accumulation of organic matter in the plant depends not only on the mean daily temperature, but especially on its amplitude variation within 24 hours. Therefore, best conditions for accumulation organic matter are favoured by the low nighttime (14-16 °C) and relatively high daytime (20-30 °C) temperatures (Sandu et al., 2010).

On an annual average, over the analysed period (1961-2007), the air temperature increases from west to east, ranging between 11.9 °C at Gura Portiţei weather station to °C 11.0 at Jurilovca weather station. These variations are determined by the increasing influence of the Black Sea upon the inland territory. The *mean monthly temperatures* highlight the thermal contrasts between the extreme seasons on one hand (Figure 3.9) and monthly on the other (Table 3.8).

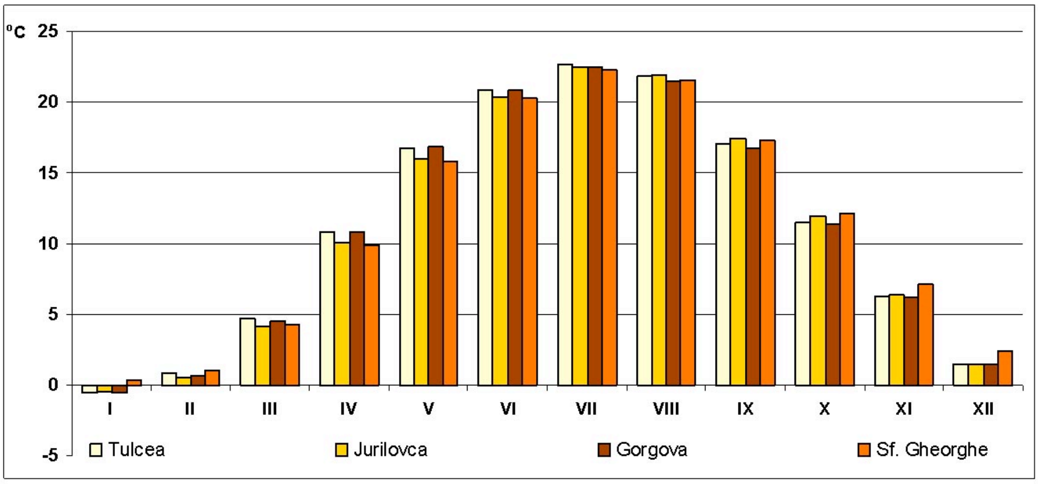


Figure 3.9. Mean annual air temperatures in the Danube Delta Biosphere Reserve (1961-2007) (Source: processed after the National Meteorological Administration database)

Table 3.8. The highest (max.) and the lowest (min) mean monthly and annual air temperature at relevant weather stations in the Danube Delta Biosphere Reserve (1961-2007)

Weather station	T. min/max	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Tulcea	*max*	5.3	6.5	9.2	13.7	19.6	23.2	25.7	24.6	20.7	15.3	10.3	5.7	12.9
	min	-8.2	-7.7	-1.6	7.2	14.6	19.1	20.4	18.9	14.6	9.4	0.6	-3.8	9.6
Jurilovca	*max*	4.9	5.8	8.1	12.6	18.5	22.7	25.9	24.6	21.4	16.5	10.5	4.9	12.5
	min	-7.6	-7.3	-2.0	6.9	13.6	18.5	20.3	18.6	14.7	9.8	0.9	-3.1	9.4
Gorgova	*max*	4.9	5.6	8.1	13.2	19.3	23.3	25.5	24.0	20.3	15.5	10.4	5.2	12.8
	min	-8.1	-7.6	-1.5	7.3	14.6	19.1	20.6	18.4	14.6	9.1	1.0	-3.3	9.5
Sfântu Gheorghe	*max*	5.1	5.8	7.6	12.2	18.5	22.8	25.4	23.8	20.9	16.7	11.4	5.8	14.7
	min	-6.5	-7.4	-1.7	6.7	13.6	18.7	20.2	17.9	15.0	9.5	1.9	-2.2	7.1

Source: processed after Sandu et al., 2008

Monthly average of daily extreme temperatures have a significant role in the distribution of different phenological phases, as they are calculated from instantaneous values at different moments of the day, measured with maximum-minimum thermometers, representing the real contrasts between day and night. In January monthly averages of daily maximum temperatures are positive, ranging from 3 to 4 °C in the entire area, increasing in July to over 25 °C in the Marine Delta and Razim-Sinoe Lagoon Complex, over 26 ºC in the central regions of the Danube Delta and over 27 º C in the western parts.

Monthly averages of daily minimum temperatures in January are the result of specific cooling processes moderated by the Black Sea and Danube River influences, so that they reach the highest values in the entire country, rarely dropping below -3 °C in the coastal zone, or -5 °C in central and western Danube Delta. In July, they rise up to around 18 °C -19 °C.

The *mean thermal contrasts* between winter and summer daily temperature extremes points to the climatic continentalism of the region. In the Danube Delta Biosphere Reserve these differences increase in value from the Black Sea (below 28 ºC) towards west as it reduces its influence, up to 30-32 °C in Tulcea.

Mean daily temperatures. In the Danube Delta Biosphere Reserve the characteristics of the intervals with significant mean daily temperatures were determined statistically, based on histogram method and specific parameters: first and last day of the interval, duration and the amount of temperatures exceeding the selected threshold (Table 3.9). The importance of these thermal thresholds is mainly related to certain environmental features of a region in terms of reaching or exceeding a specific amount of degrees or days with characteristic temperatures required in triggering particular plant phenophases.

Table 3.9. Climatic parameters of the mean daily intervals above and below certain thermal thresholds characteristic for the main weaher stations in the Danube Delta Biosphere Reserve

Weather station	First day	Last day	The length of the interval	The sum of temperatures
Annual interval with mean daily positive temperatures (≥ 0 ºC)				
Tulcea	11.02 - 21.02	21.12 - 1.01	325 – 350	4000 - 4100
Jurilovca	1. 02 – 11.02	after 1.01	325 – 350	4000 - 4100
Gorgova	1. 02 – 11.02	21.12 - 1.01	325 – 350	4100 - 4150
Sfântu Gheorghe Deltă	before 1.02	after 1.01	350 – 360	4150 - 4200
Gura Portiţei	1. 02 – 11.02	after 1.01	325 – 350	4000 - 4100
Annual interval with mean daily temperatures of ≥ 5 ºC				
Tulcea	before 21.03	11.11 – 21.11	240-250	≥ 4000
Jurilovca	1.04 - 11.04	21.11 – 1.12	240-250	3900-4000
Gorgova	before 21.03	21.11 – 1.12	240-250	3900-4000
Sfântu Gheorghe Deltă	21.03 - 1.04	21.11 – 1.12	250-275	3900-4000
Gura Portiţei	21.03 - 1.04	21.11 – 1.12	240-250	3900-4000
Annual interval with mean daily temperatures of ≥ 10 ºC				
Tulcea	11.04 – 21.04	21.10 – 1.11	240 – 250	3400 - 3600
Jurilovca	11.04 – 21.04	21.10 – 1.11	240 – 250	3400 – 3600
Gorgova	11.04 – 21.04	21.10 – 1.11	240 - 250	3400 – 3600
Sfântu Gheorghe Deltă	11.04 – 21.04	21.10 – 1.11	250 - 275	3400 – 3600
Gura Portiţei	11.04 – 21.04	21.10 – 1.11	240 - 250	3400 - 3600

(Source: processed after the National Meteorological Administration database)

The intensity of cooling processes during the cold season and heating of the hot season is highlighted by the annual (Table 3.10) and monthly (Table 3.11) frequency of *days with different characteristic temperatures*. The summer and winter days with different characteristic temperatures have a strong influence on the vegetative cycle of ITPS in terms of frequency and intensity.

Table 3.10. Mean annual frequency of days with different characteristic temperatures in the Danube Delta Biosphere Reserve (1961-2007)

Weather station	**Winter days** *(T max.<0 ºC)*	**Frosty nights** *(Tmin≤-10 ºC)*	**Summer days** *(Tmax.≥25 ºC)*	**Tropical days** *(Tmax≥30 ºC)*
Tulcea	19.9	9.2	88.3	21.7
Jurilovca	16.6	7.2	75.1	12.7
Gorgova	19.2	8.2	81.0	13.8
Sf. Gheorghe	13.5	5.9	62.2	5.4

(Source: processed after the National Meteorological Administration database)

As a result of this specific climatic conditions, winter (frost and hoarfrost, glazed frost, snowfalls, blizzards, snow cover etc.) and summer (heat waves, heavy rainfall, aridity and drought etc.) extreme phenomena are less frequent and intense in the study-are as compared to other plain regions in the southern and south-eastern Romania.

Table 3.11. Relevant summer/winter frequency of days with different characteristic temperatures (annual average) in the Danube Delta Biosphere Reserve (1961-2007)

Weather station	IX	X	XI	XII	I	II	III	IV	IV	V	VI	VII	VIII	IX	X	XI
	Frosty nights (T min ≤ -10 ºC)								*Summer days (T max ≥ 25 ºC)*							
Tulcea			0.2	1.4	4.7	2.4	0.5		0.8	7.9	18.2	24.3	24.0	11.5	1.4	0.1
Jurilovca				0.2	4.1	2.0	0.4		0.3	3.9	14.2	24.8	23.0	8.3	0.5	0.1
Gorgova			0.1	1.2	4.4	2.2	0.3		0.5	5.6	17.4	24.6	22.3	10.0	0.6	
Sf. Gheorghe				0.6	3.4	1.6	0.3		0.1	1.8	11.5	21.8	21.4	5.4	0.2	
	Frosty days (T min ≤ 0 ºC)								*Tropical days (T max ≥ 30ºC)*							
Tulcea	0.1	2.1	8.3	18.4	23.8	19.0	11.6	0.6		0.4	4.1	8.1	7.5	1.6		
Jurilovca		0.8	7.2	17.6	23.8	18.7	11.6	0.6		0.1	2.0	5.2	5.1	0.3		
Gorgova	0.1	1.2	8.6	18.4	24.3	19.2	10.8	0.3		0.2	2.6	5.5	5.1	0.4		
Sf. Gheorghe	0.0	1.1	6.3	15.9	21.7	17.4	9.5	0.4			0.7	2.6	1.9	0.2		
	Winter days (T max ≤ 0 ºC)								*Tropical nights (T min ≥ 20 ºC)*							
Tulcea			0.4	4.1	8.8	5.3	1.3				0.9	3.0	1.9	0.2		
Jurilovca			0.3	3.0	7.3	4.7	1.3				1.4	4.5	4.1	0.2		
Gorgova			0.4	3.6	8.3	5.4	1.5				2.3	5.2	2.2			
Sf. Gheorghe			0.2	2.0	5.8	4.3	1.2				1.3	4.1	3.1			

(Source: processed after the National Meteorological Administration database)

An important role in assessing the vegetative cycle of plants is played by the ***soil temperature*** which converts the soil surface into the main source of heat. In the Danube Delta Biosphere Reserve, the soil temperature parameters rage in mean annual values between 12-13°C (Figure 3.10).

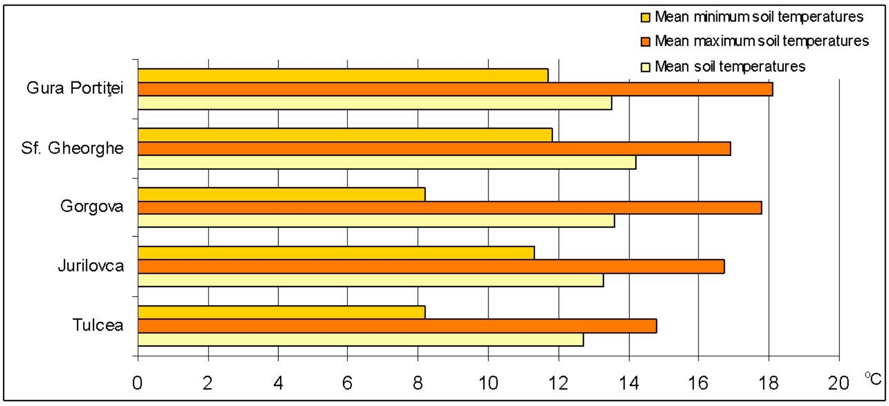


Figure 3.10. Mean annual soil temperature in the Danube Delta Biosphere Reserve (1961-2007)
(Source: processed after the National Meteorological Administration database)

Throughout the year, the minimum soil temperatures are reached in January (0º ... -2ºC) in relation to the negative temperatures and shallow snow layer (or even absent in some years). The maximum values could rise up 25-27 ºC in July, favoured by the long periods of insolation, high humidity, lower altitudes, vegetation cover etc.

With regard to the ***frost phenomenon***, of high importance is the *annual frost free interval* (with minimum air and soil level temperature of ≥0°C) having major influences in the development/restraining of vegetal phenophases. In the Danube Delta Biosphere Reserve the multiannual average of this parameter varies between 190-200 days in the fluvial-marine area and 180-190 days in the Razim-Sinoie Lagoon Complex.
The *first ground frost* occurs in the second decade of October in the western and central parts of Danube Delta, going up to the first decade of November in the eastern and south-eastern extremity. The *last frost* occurs on average in the second decade of April throughout the Danube Delta area.

The air saturation with water vapours - **relative air humidity (RU)** - which is mainly related to the large water and vegetation-covered surfaces in the Danube Delta, displays mean annual values of over 80%, higher during winter (exceeding 90% in December at Sf. Gheorghe weather station).

The average frequency of "dry days" (where RU ≤ 30%) registers less than 5 days both annually and during the warm semester of the year. The number of "humid days" (RU ≥ 80% at 1 PM) displays a maximum frequency during the cold semester of the year in the Danube Delta Biosphere Reserve (up to 135.6 days at Sf. Gheorghe weather station).

Among the key meteorological features of the study-area **precipitation** amounts have an important role in the development and spread of ITPS. On an annual regime, it shows a significant variability of the periodic and non-periodic hydric regime, increasing in quantities from east (346.1 mm at Sf. Gheorghe) to south-west (376.4 mm at Jurilovca), centre (390.2 mm at Gorgova) and west (461.3 mm at Tulcea), thus registering a spatial variations of over 115 mm (Figure 3.11).

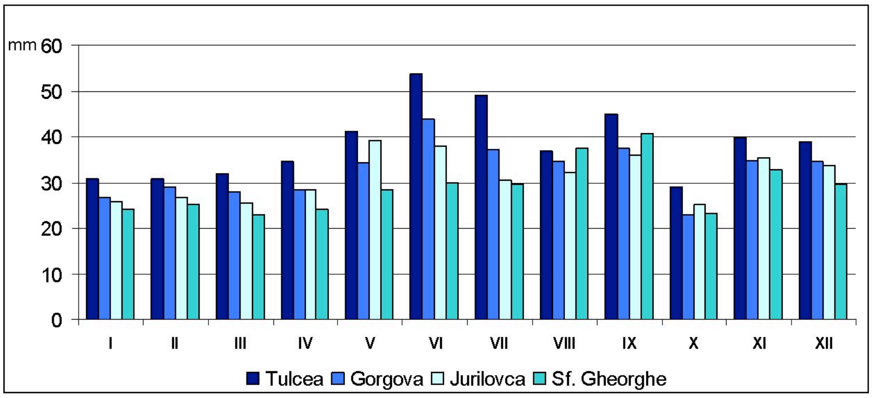


Figure 3.11. Mean annual precipitation amounts in the Danube Delta Biosphere Reserve (1961-2007) (Source: Dragotă 2006)

The largest share of seasonal precipitation amounts is registered during the warm semester, when most of ITPS vegetative cycle is at its highest peak (Fig. 12). The values can reach between 132 mm (September 1996 at Sf. Gheorghe) and 191 mm (June, 1997 at Tulcea), June and July being the richest months and February and October the poorest (Dragotă 2006).

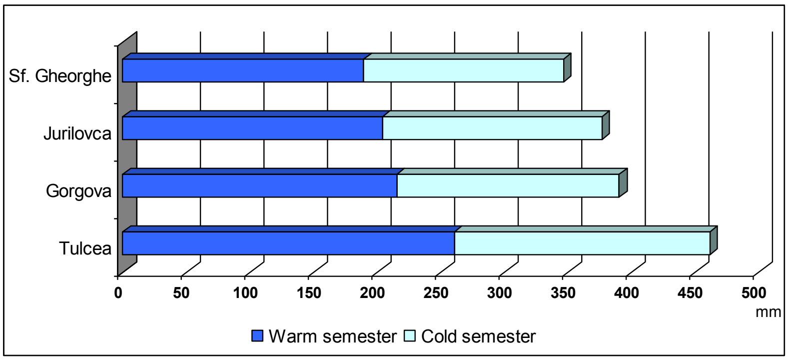


Figure 3.12. Seasonal precipitation amounts registered during the warm and cold semesters in the Danube Delta Biosphere Reserve (1961-2007) (Source: Dragotă 2006)

The pluvial characteristics of the 1961-2007 period shows significant annual fluctuations in the precipitation amounts outlining several distinctive deficit (1983, 1994, 2000, 2006, 2007) and excess (1966, 1997, 1999, 2005) rainfall years. Coupled with warmer or colder periods, these pluvial extremes trigger negative impacts on the growing season of humidity/drought-loving ITPS *Amorpha fruticosa, Fraxinus pennsylvanica, Acer negundo, Robinia pseudoacacia, Ailanthus altissima* etc. Therefore, precipitation parameters may affect the optimal development of the vegetative cycle during the active growth period and may influence the dissemination of ITPS, especially when it comes to hydrocoric seed propagation for the species having high seed abundance index.

The **wind** parameters, mainly in terms of speed and frequency, act as key driver in the dissemination of ITPS in relation to their main biological features (propagation and dispersal type etc.). In general, the predominant wind direction in the Danube Delta Biosphere Reserve is northern and the *average speed no matter the direction* ranges between 4 and 6 m/s.

The most significant local winds are *breezes*, formed due to thermal contrast between the land and water. The diurnal breeze system refers to the land breeze which occurs at night having maximum intensity between 11 PM and 7 AM and the sea breeze which reaches its highest values during the day, between 10 AM and 8 PM.

Dangerous climatic phenomena in terms of high intensity and frequency contribute differently to providing favourable/unfavourable conditions for the development of ITPS phenonophases, thus having a mechanical effect on plants (e.g. frost and hoarfrost, glazed frost, heavy rainfall, strong winds etc.). Among all the analysed climatic parameters and meteorological elements involved in the dynamics of ITPS some of them range first when discussing their action as drivers in the distribution and spread of these plant species.

Thus, early or late frosts and hoarfrosts, aridity and drought, heavy rain falls, hail storms, strong winds, blizzards, etc. through their physiological and mechanical effects distort, break or cause temporary imbalances in the natural evolution of vegetation.

Discussions. Assessing the key environmental drivers in relation to the dynamics of the invasive plant species is a critical component of the conservation management. Therefore, including spatially explicit projections of how global (climate) change alters natural habitats and flora (Bradely et al., 2010) should be integrated in the long-term planning of each protected area. As a consequence, relating local environmental features on one hand (slope, soil, water etc.) and the meteo-climatic parameters on the other, for the achievement of optimum thermal, hydric and aeolian conditions for the development of ITPS (in relation to their specific bioclimatic requirements) have a key role in their distribution and spread.

In the Danube Delta Biosphere Reserve, all these general and local climatic features provide the favourable framework for the optimal development of existing ITPS, concurrently indicating the expansion/reduction probability of areas they occupy, thus becoming a real ecological threat for important vulnerable habitats such as: Mediterranean salt meadows; Western Pontic saltmarsh rush saline meadows; Sarmatic *Carex distans* saline meadows; North-Western Pontic *Ephedra – Carex* fixed dunes etc. (Doroftei, 2009a; 2009b).

Therefore, preventing the aggressive spread of invasive species into fragile ecosystems, such as Danube Delta Biosphere Reserve, requires thorough investigations on the main environmental drivers such as climate (e.g. climatic parameters, extreme weather events etc.) in terms of data processing, distribution maps, correlations with biological parameters of plants, integrative indexes etc. able to provide effective awareness on the types of species that are threatening native habitats.

3.4. Integrated methodology and data - potential distribution of ITPS in the Romanian Protected Areas (IGAR)

The developed integrated methodology relies on in-depth cross-references in the biological and geographical scientific literature on the most relevant invasive terrestrial plant species in the Romanian protected areas: *Amorpha fruticosa, Acer negundo*, *Ailanthus altissima* and *Fallopia japonica.* Aditionally, based on the complex assessment of spatial (investigation and GIS processing of the most relevant cartographical materials: topographical, geological, hidrogeological, soil, vegetation maps, aerial photographs etc.), statistical data (biological and geographical scientific literature) as well as field surveys, an ***invasive terrestrial plant species potential distribution model (ITPS-podismod)*** was developed. **ITPS-podismod** is a model aiming to assess the distribution potential of ITPS in relation to the particularities of each species' main ecological requirements in a certain area. The model is based on several steps (Figure 3.13).

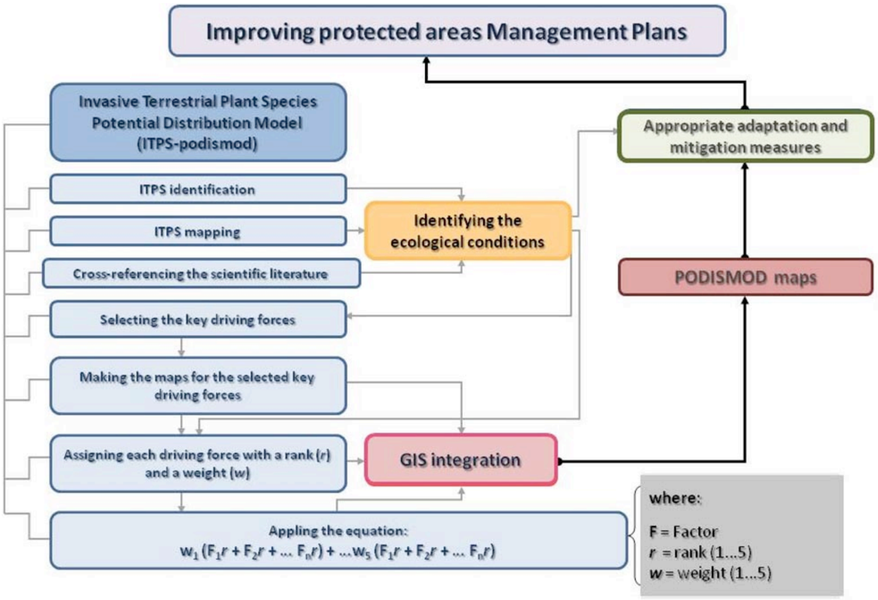


Figure 3.13. ITPS podismod scheme

Firstly, the authors mapped the selected species in order to identify their habitat description and the key factors **(F)** responsible for their potential distribution. In relation to these particular ecological features, each key factor was evaluated on a 1 to 5 scale and assigned with a ***rank (r)*** indicating the relationship between each attribute and species spreading potential. For example, when referring to the role of soils in spreading of *Amorpha fruticosa*, the Luvisols were assigned with a *maximum rank* (r=5), and the Salsodisols and Anthrisols the *minimum rank* (r=1). Concurrently, each key factor was assigned with ***weight* (*w*)** from 1 to 5, representing its importance among the considered ecological drivers.

For example, in the case of *Amorpha fruticosa*, soil texture was assigned with *maximum weight* (w=5) and the slopes exposure with *minimum weight* (w=1). The index was computed according to the following mathematical equation:

$$w_1(\mathbf{F1_r} + \mathbf{F2_r} + \ldots \mathbf{Fn_r}) + \ldots w_5(\mathbf{F1_r} + \mathbf{F2_r} + \ldots \mathbf{Fn_r})$$

where: w= *weigh (1…5); **F1, F2, … Fn** = driving forces; **r** = rank (1…5);*

The model is taking into several key factors **(F)** according the particularities of each analyzed protected area (Table 3.12).

Table 3.12. The *w* (weigh) value assigned to the key drivers

Driving forces	**Comana Natural Park**	**Rodna Mountains National Park**	**Măcin Mountains National Park**	**Maramureş Mountains Natural Park**
Temperature (T)	-	5	-	
Hypsometry (H)	-	5	2	1
Declivity (D)	-	2	3	3
Slopes exposure (Se)	1	5	5	2
Soil type (S)	5	5	4	5
Soil texture (St)	5	5	2	3
Land use/land cover (LUC)	5	3	3	4
Mining areas (Ma)	-	3	-	-
Areas disturbed by storms (Ds)	-	4	-	-
Wetland buffer (WB)	5	-	-	-
Distance to rivers (Dr)	4	-	-	5
Railway buffer (RwB)	4	-	-	-
Main modernised roads buffer (RB)	3	-	-	-
Forest roads buffer (FrB)	-	4	-	-
Sheepfolds buffer (SfB)	-	2	-	-

Subsequently, based on assigned ***rank (r)*** and ***weigh (w)*** according to the particularities of the considered key driving forces, a mathematical relation for each analysed species in the selected protected areas has resulted. Based on this particular approach, the authors were able to obtain the ***ITPS-podismod index*** values characteristic for each protected area showing the distribution potential for the analyzed species: ***very low, low, medium, high, very high***.

3.4.1. Comana Natural Park Case Study (IGAR)

Comana Natural Park has granted the protected area status even since 1954 by declaring Comana Forest (630.5 ha) as natural reserve. Recently, according to the IUCN Categories and national regulations the entire protected area falls into the *5th category – Protected terrestrial ecosystems*. Some internal small-size protected areas belong to the *4th IUCN category – Natural reserves*: Oloaga-Grădinari Forest and Padina Tătarului Forest. Due to its position in the central-eastern part of the Romanian Plain at the biogeographic limit between mesophyllous deciduous forests and the sylvo-steppe, the study-area has favoured the development of different floristic and faunistic associations of different geographical origin. Additionally, its position at the crossing point of many floristic provinces explains the biodiversity given by the large number of taxa, the great number of endemic species (*Achillea getica, Dianthus trifasciculatus ssp. desertus, Viola jooi, Paeonia peregrina var. romanica*) and species with different geographical origin (*Ruscus aculeatus, Convalaria majalis, Crocus moesiacus* etc.). Until the beginning of the 19th century, the study-area was covered by Vlăsia Secular Forest, whose remnant patches appear as left-over of the one of the best-preserved forests in Europe. Currently, these protected areas are almost entirely overlapping the ***Natura 2000 Network*** (*SPA – Special Protection Areas* and *SCI - Site of Community Importance*) aiming to protect wildlife and its habitats (Grigorescu et al., 2013).

Over the last century, the natural ecosystems of these protected areas were massively transformed by human activity trough deforestation, overgrazing etc. and replaced with secondary meadow and scrub associations, strongly affecting the floristic structure and composition. The complex investigations undertaken before 2010-2012 in Comana Natural Park have revealed that the ITPS with the highest impact on local habitats is ***Amorpha fruticosa*** (the desert false indigo or the indigo bush).

Amorpha fruticosa is an ITPS originating from the south-eastern part of North America. It was introduced in Romania in the first half of the last century for decorative purposes. Subsequently it penetrated the natural *Populus* and *Salix* forests along the Danube River. After 1985 it has spread upon broader areas proving a high capacity of widening its habitat (Stănescu et al., 1997; Dumitraşcu et al., 2010). Presently, the plant is adapted to all types of environment, but it prefers especially the wetlands from Danube Flodplain and Danube Delta (Anastasiu & Negrean, 2005; Anastasiu et al., 2008; Dihoru, 2004; Doroftei, 2009a, 2009b). It can also be adapted to reduced soil moisture which characterise the sylvosteppe soils of Comana Natural Park. Recent studies stated that *Amorpha fruticosa* develops very well on metal-contaminated soils (lead, zinc, copper, nickel, etc.), on tailing ponds as incipient species together with other fast-growing non-native and native species or on fertilized terrains (Li, 2006; Seo et al., 2008; Marian et al., 2010; Xiang, 2011). The multiplication and spread are made by means of seeds, rarely by sprouts or layering which explains its high dissemination capacity. *Amorpha* has a symbiotic relationship with certain soil bacteria fixing atmospheric nitrogen (Huxley, 1992).

According to the assigned ***rank (r)*** and ***weight (w)*** in the study-area, the mathematical formula which becomes:

$$1\mathbf{Se}_r + 3\mathbf{RB}_r + 4(\mathbf{TsB}_r + \mathbf{RwB}_r) + 5(\mathbf{S}_r + \mathbf{St}_r + \mathbf{WB}_r + \mathbf{LUC}_r)$$

As a result, the final ***ITPS-podismod index*** values characteristic for *Amorpha* in the Comana Natural Park display the following distribution potential (Table 3.13):

Table 3.13. ITPS-podismod index values

Distribution potential	Interval
very high	> 132
high	110 - 132
medium	75 - 109
low	45 - 74
very low	< 45

Local key environmental driving forces. Based on the **ITPS-podismod**, the main environmental driving forces used for assessing the potential distribution of *Amorpha fruticosa* in the Comana Natural Park are the following (Figure 3.14).

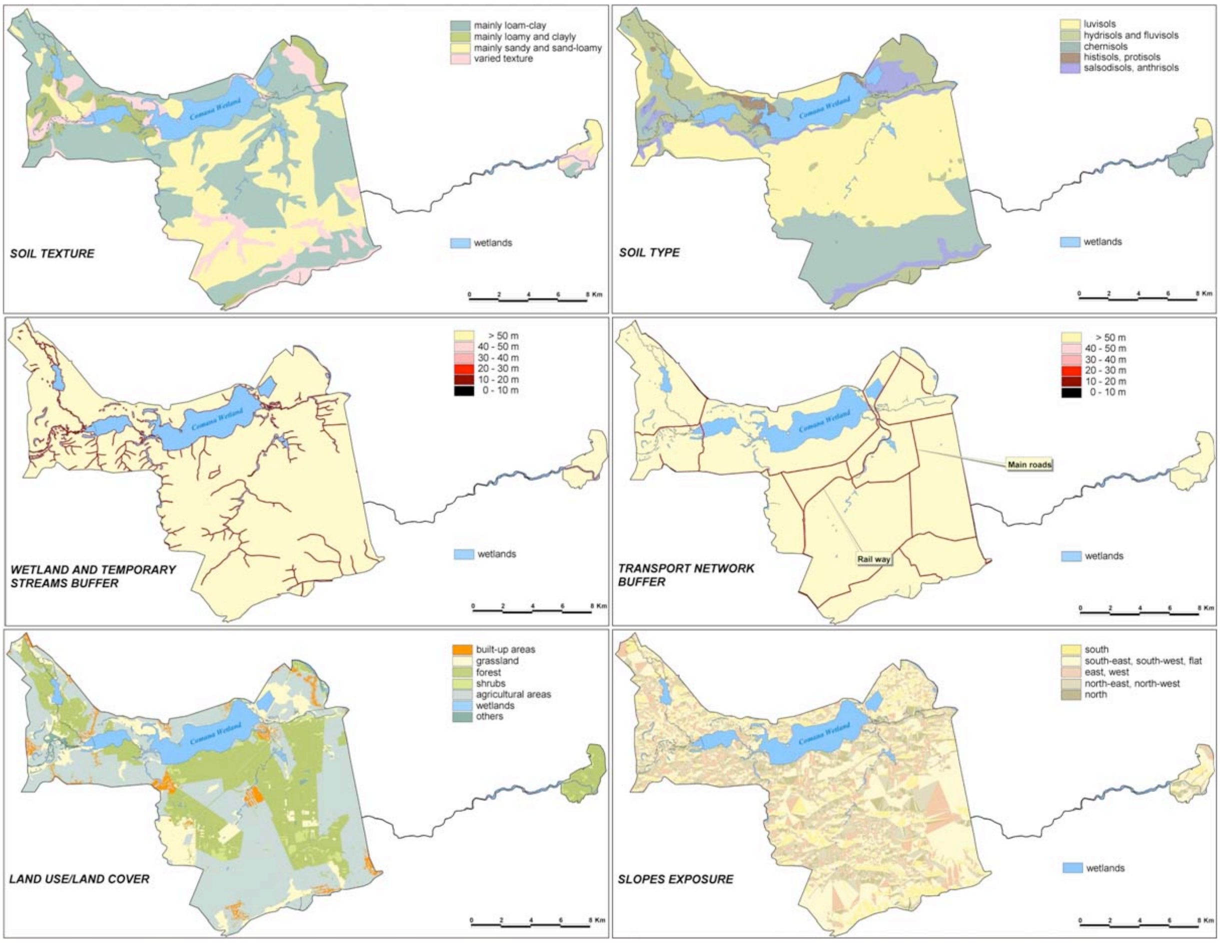


Figure 3.14. Local environmental driving forces' maps in the Comana Natural Park

Soil type and texture. The largest surface of the Park is covered by reddish-brown soils which are widely spread in the central and northern areas. The soil texture is generally loamy and loam clay and rarely loam sandy and loam clay. On extended areas in the south and east, haplic chernozems and luvic phaeozems, with loam, loam clay, and varied texture can be found. In the northern part of the study-area there are fluvisols and alluvial soils in different evolution stages with loam sandy, loam clay or varied textures. When discussing the role of soils properties in the development of *Amorpha fruticosa*, the mapping undertaken so far have revealed an exclusive preference of the specie for reddish-brown soils (reddish-brown typical sub-type) with loam clay texture. This soil type has deep profile (1.2–1.6 m) and a clay substance of about 30-40%. It is also enriched in nitrogen, potassium and phosphorus.

Land use/land cover based on orthophotoplans takes into consideration as the main drivers having a certain impact on specie's distribution the following: ***agricultural land*** - studies undertaken in USA, China and Korea on phytoremediation revealed that increased fertilization, mainly of organic nature, had improved the growth of *Amorpha sp.* (Li, 2006; Seo et al., 2008; Marian et al., 2010; Xiang, 2011); ***grasslands and shrubs*** - recent studies showed that indigo bush has increased its invasive potential on these land use categories, thus having negative effects on the native vegetation (Sărăţeanu, 2010); ***wetlands*** – even though they appear to be more susceptible to invasion than other ecosystems acting like natural drivers and dispersal agents facilitating the spread of the species (Fenesi et al., 2009), in the study-area we have considered this category as being quite restrictive. However the specie prefers the wetlands' surrounding areas, including temporary streams and the euthrophised ponds due to soil enrichment in organic matter. Ex. significant exemplars were found in Brăniştari village where it spreads upon the reed habitats (*Phragmites communis*) trying to substitute them (Figure 3.15, C); ***forests*** – generally speaking, they represent a limitative factor for the spreading potential but in the study-area we have considered them as favourable drivers in terms of plant's preference for forests outskirts using an inner buffer of up to 50 m.

Transport network. The excellent development of the specie on contaminated areas (Li, 2006; Seo et al., 2008; Marian et al., 2010; Xiang, 2011) explains its largest spread on the spoiled soils located along the non-electrificated railroad which connects Comana to Mihai Bravu villages (Figure 3.15, B) or on the European road connecting Călugăreni and Uzunu localities. These areas also represent introduction and spreading pathways.

Slopes exposure. Due to its preference for light, *Amorpha* is mainly developing on sunny slopes with southern, south-eastern and south-western orientation.

Figure 3.15. *Amorpha fruticosa* – main habitats in the Comana Natural Park

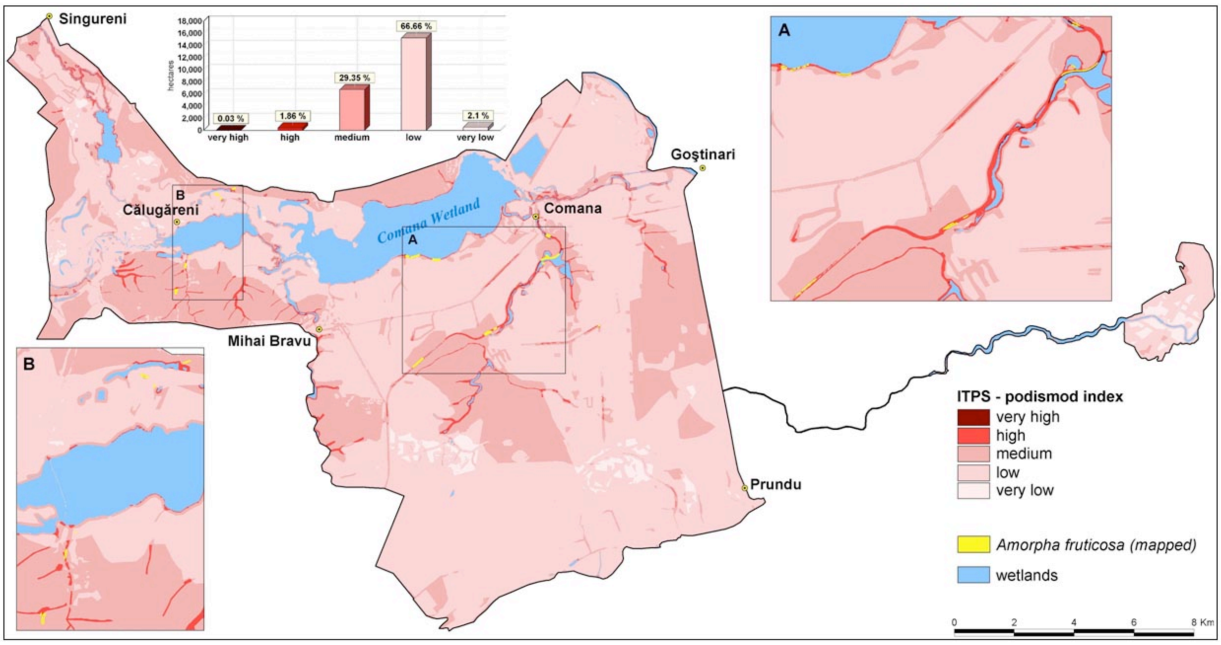


Figure 3.16: Potential distribution of the invasive terrestrial plant species in the Comana Natural Park according to ITPS-podismod index

Discussions. The outcome of *Amorpha fruticosa* **ITPS-podismod** reveals index values which highlight certain homogeneity of the potential distribution areas in relation with the specie key environmental factors distribution and weight. Therefore, nearly 2% of Park's area displays a high and very high potential mainly favoured by the vicinity of wetlands, the presence of Luvisols with loam-clay texture and by the spoiled soils located along the railroad which connects Comana and Mihai Bravu. Medium values cover roughly 30% of Park's area located in the central and western parts as they are largely favoured by the soil type and texture as well as by the development of shrubs and grasslands. The prevalence of Cernisols with sandy and sand-loamy texture under forests and agricultural-covered areas as restrictive factors in the distribution of *Amorpha fruticosa*, determines a low (67%) and very low (2%) potential (Figure 3.16).

After completing the ITPS-podismod model, in order to examine as accurate as possible the relationship between the model and the real distribution of the specie, further mapping were undertaken in the spring of 2011. Herby, a quite perfect relationship can be distinguished in terms of overlapping the *Amorpha* natural habitats with the areas displaying very high and high potential (82%), as well as medium potential (18%).

3.4.2. Rodna Mountains National Park Case Study (IGAR)

Rodna Mountains National Park, 2nd IUCN category, is part of the Rodna Mountains situated in the North of Romania, approximately in the central part of the Carpathian Chain. The Park lies between 700 m and 2,303 m (Pietrosu Peak), featuring one of the most imposing alpine landscapes in the Romanian Carpathians that preserves the most representative glacial and periglacial landforms (Kucsicsa 2010). Rodna Mountains National Park is the biggest national park in the Eastern Carpathian Chain (46,399 ha), out of which 3,300 ha were declared ever since 1979 Biosphere Reserve in the framework of UNESCO-MAB Programme. The Park's forests, meadows and rocky places shelter rich fauna and flora with various rare and endemic Carpathian-origin species (*Lychnis nivalis, Festuca versicolor ssp. dominii,* and *Minuartia verna ssp. oxypetala* etc.). The Park displays the whole range of high mountain ecosystems, and an Alpine realm representative for Romania (Dragotă and Kucsicsa 2011). Since 2001, by means of Law no. 462, the entire Park's area was declared Biosphere Reserve.

Studies conducted in the study-area point to ***Ailanthus altissima*** (Chinese sumac or the three of heaven) as one of the main ITPS.

Ailanthus altissima is an invasive toxic pioneer species (Burch and Zedaker, 2003) considered as one of the most aggressive in Europe because it penetrates into natural vegetation and irreversibly changes its composition. It is a deciduous three native to China introduced into Europe (firstly to England and France) in the late 18th century as an ornamental species. *Ailanthus* spreading capacity is highlighted by its fast propagation (up to 350,000 seeds in a year) and rapid growth (up to 3 cm per day). The root system is aggressive enough to cause damage to sewers and foundations. Its pollen is a known allergen and its bark and leaves produces a toxic substance (allelopathic) that prevent the establishment of other plant species (Feret, 1985; Lawrence et al., 1991). It can tolerate abandoned fields, railroad embankments, roadsides, waste grounds, and other disturbed sites (Landenberger et al., 2006), as well as a wide range of pH conditions (Feret, 1985). The species is also drought resistant which made its broad expansion possible (Trifilo et al., 2004). In naturally forested areas, it may establish in areas disturbed by storms or infestations mainly related to insects' strokes. *Ailanthus* is well adapted to heavy clays and other soils with low nutrient and oxygen content (Burch and Zedaker, 2003; NBII & IUCN/SSC ISSG, 2005).

For Rodna Mountains National Park, according to the assigned ***rank (r)*** and ***weight (w)*** for the analysed species, the mathematical formula becomes:

$$2(\mathbf{D}_r+\mathbf{SfB}_r) + 3(\mathbf{LUC}_r + \mathbf{Ma}_r) + 4(\mathbf{FrB}_r + \mathbf{Ds}_r) + 5(\mathbf{T}_r + \mathbf{S}_r + \mathbf{St}_r + \mathbf{Se}_r + \mathbf{H}_r)$$ where:

1, 3, 4, 5 = w**;** r = rank;

Therefore, the final ***ITPS-podismod index*** which displays the distribution potential values reveals the following intervals/classes (Table 3.14) (Dumitraşcu et al., 2011c).

Table 3.14. ITPS-podismod index values

Distribution potential	Interval
very high	> 164
high	133-164
medium	99-132
low	66-98
very low	< 66

Local key environmental driving forces. Based on the **ITPS-podismod**, the main environmental driving forces used for assessing the potential distribution *Ailantus altissima* in the Rodna Mountains National Park are the following:

Soil type and texture. The prevalence of metamorphic and crystalline shists had determined the development of oligo-basic and acid soils (e.g. dystric cambisols and entic podzols) with high matter content and reduced depth. When discussing the role of soils properties in the development of ITPS, the mapping undertaken so far have revealed an exclusive preference of *Ailanthus altissima* for dystric cambisols with loamy-sandy to loamy-clay texture.

Land use/land cover based on orthophotoplans takes into consideration as the main drivers having a certain impact on species' distribution the following: ***grasslands and shrubs*** - recent studies showed that indigo bush has improved its invasive potential on these land use categories with negative effects on the native vegetation (Sărăţeanu 2010). When discussing *Ailanthus*, field surveys had identified the specie well developed on grasslands; ***forests*** – represent rather a limitative factor; ***bare rocks*** also represent a limiting driver for the development of ligneous vegetation.

Transport network is another key driving factor both as pollution source (Li 2006; Seo et al., 2008; Marian et al., 2010; Xiang 2011) and introduction/spreading pathway. Additionally, ***forest roads*** represent potential spreading areas for *Ailanthus.*

Slopes exposure. Due to its preference for light, *Ailanthus* is mainly developing on sunny southern, south-eastern and south-western slopes.

Hypsometry and **declivity** are important drivers for this ITPS. Hypsometry determines an altitudinal distribution of all environmental factors while an accentuated declivity represents a limiting factor for the development of *Ailanthus.*

Temperature is another important driving force for *Ailanthus*. It varies with altitude and relief configuration, thus limiting the distribution of species towards higher altitudes.

Mining areas. The long-term mining activities (active until 2000) that have affected Rodna Mountains and *Ailanthus'* preference for spoiled and degraded terrains, point to a high potential spread inside mining sites.

Storms disturbed areas. *Ailanthus* prefers disturbed forest ecosystems affected by extreme events (wind/snow felling).

Discussions. In the Rodna Mountains National Park the index values rich around 22% largely favoured by the temperature, slope exposure, the presence of disturbing sites etc. Medium values cover roughly and 45% while the low and very low potential *Ailanthus* displays values totalling almost 33% (Figure 3.17).

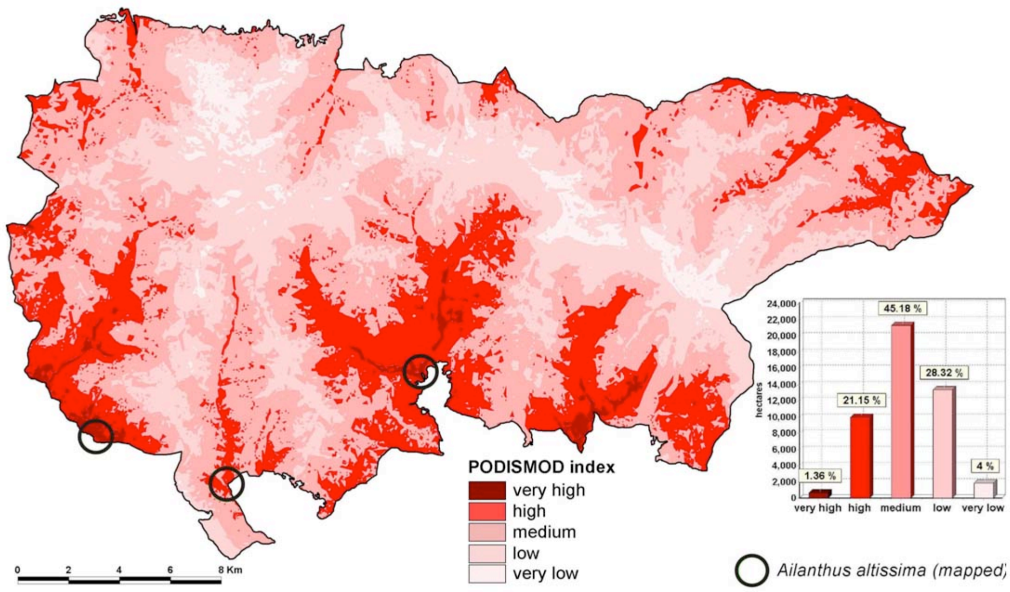


Figure 3.17. Potential distribution of *Ailanthus altissima* in the Rodna Mountains National Park (ITPS-podismod index)

3.4.3. Măcin Mountains National Park Case Study (IGAR + DDNI)

Măcin Mountains National Park (II IUCN category) is located in the south-eastern part of Romania (Northern Dobrogea Region) at the crossroads of biogeographical regions, hosting complex flora and fauna - a combination of Pontic, steppe and well-preserved Submediterranean and Balkan forest ecosystems (E.g. Luncaviţa beech forest, a Tertiary relict). It is the only protected area sheltering old Hercynian Mountains, no higher than 467 m, with mountain-like aspect, underlain by granites and crystalline schists.

In the Măcin Mountains National Park, the heaven mainly affects the grasslands, forest skirts, river banks, mining and disturbed sites etc. by competing and displacing the native vegetation (Sîrbu & Oprea, 2011). The control of this species is rather difficult because the mechanical eradication methods are not always efficient, therefore they must be completed with other mechanical and even chemical techniques (Meloche & Murphy, 2006). The undertaken field surveys have allowed the authors to identify and map in the Măcin Mountains National Park over 120 ha covered by *Ailanthus altissima* mainly located in the Pricopan Ridge (north-western part of the Park area), an area entirely included into the *totally protected area* category, thus indicating a higher impact on native ecosystems (Figure 3.18).

In the study-area *Ailanthus altissima* tolerates different environmental conditions ranging from brightness (shinny and semi-shinny slopes) to open areas (scrub and/or herbaceous vegetation associations) but also prefers some specific soil types (litosoils and kastanozeoms) and textures (loamy and clay loam) with a high mineral content, thus proving species' preference for spoiled and degraded terrains.

The field researches have been proved that *Ailanthus* was very well developed on the upper half of the slopes with declivities of over 5 ^{0} (over 95 %) at altitudes of 50 m – 200 m (over 90 %) (Table 3.15).

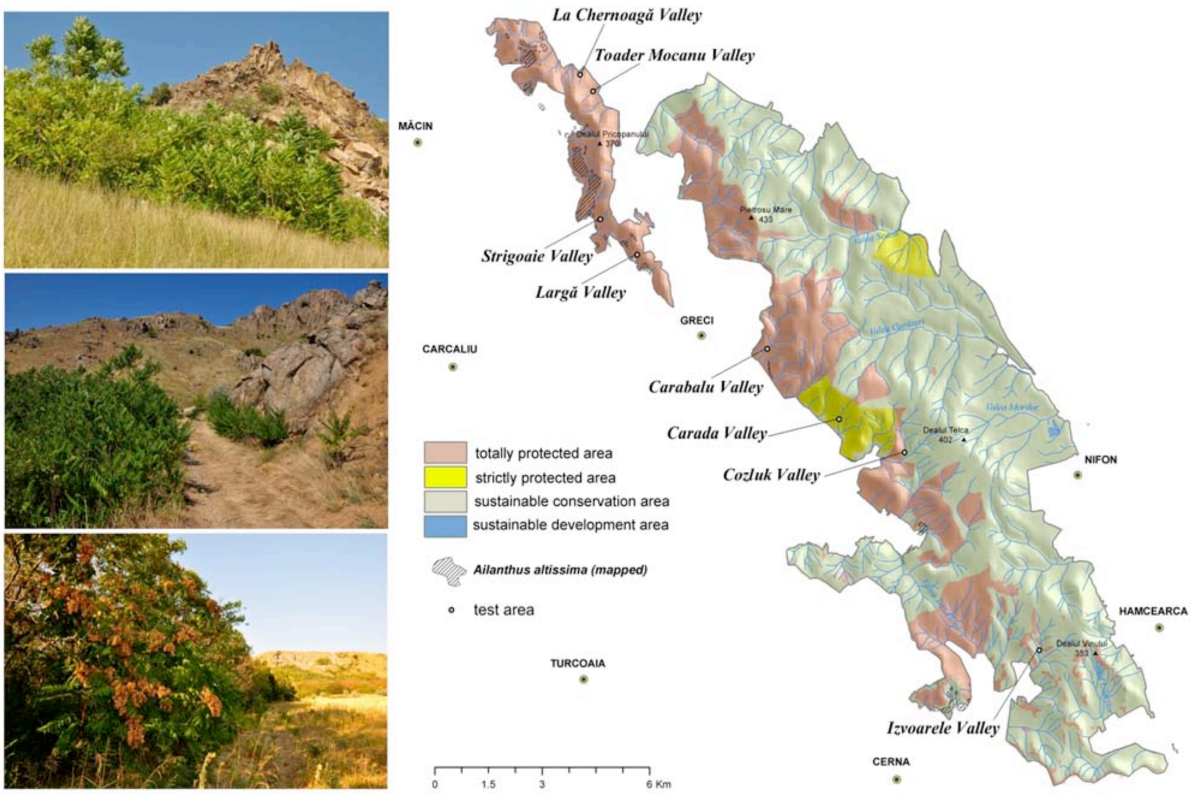


Figure 3.18. *Ailanthus altissima* in the Măcin Mountains National Park

Table 3.15. *Ailanthus altissima* distribution in relation to the analysed driving forces

by hypsometry (m)	ha	%	**by declivity (º)**	ha	%	**by slope exposure**	ha	%
< 50	3.7	2.9	< 5	5.7	4.5	shaded	6.7	5.3
50 – 100	37.7	29.6	5 - 10	39.2	30.8	semi-shaded	41.8	32.8
100 - 150	52.6	41.3	10 - 15	31.0	24.3	sunny	78.9	61.9
150 - 200	27.4	21.5	15 - 20	27.3	21.4			
> 200	6.0	4.7	> 20	24.2	19.0			
by soil type			ha	%	**by soil texture**		ha	%
chernozems			1.5	1.2	clay loam		42.1	33.0
cambic chernozems			12.2	9.6	loamy		56.1	44.0
litosoils			44.8	35.2	loamy sand …loamy		3.4	2.7
kastanozeoms			35.5	27.8	varied texture		25.8	20.3
rocky areas			25.8	20.3				
others			7.6	5.9				
by land use							ha	%
arable land/ heterogeneous agricultural areas							10.1	7.9
pastures							9.0	7.1
forests							15.3	12.0
scrub and/or herbaceous vegetation associations							80.9	63.5
Open spaces with little or no vegetation							12.1	9.5

According to the assigned ***rank (r)*** and ***weight (w)*** in the study-area, the mathematical formula which becomes:

$$5(E_r) + 4S_r + 3(LUC_r + G_r) + 2(St_r + H_r),$$ where: 2, 3, 4, 5 = w; r = rank;

The resulted ITPS-podismod index values of ITPS *Ailanthus altissima* in Măcin Mountains National Park range 33 – 93, thus being grouped into the following classes:

Table 3.16. ITPS - podismod classes

interval	ITPS - podismod	% of surface
< 45	very low	27.3
45 – 57	low	33.0
57 –69	medium	25.6
69 – 81	high	12.3
> 81	very high	1.8

Local key environmental driving forces. Based on the **ITPS-podismod**, the main environmental driving forces used for assessing the potential distribution *Ailantus altissima* in the Măcin Mountains National Park are the following: ***hypsometry, declivity, slope exposure, soil type, soil texture*** and ***land use/land cover*** (Figure 3.19).

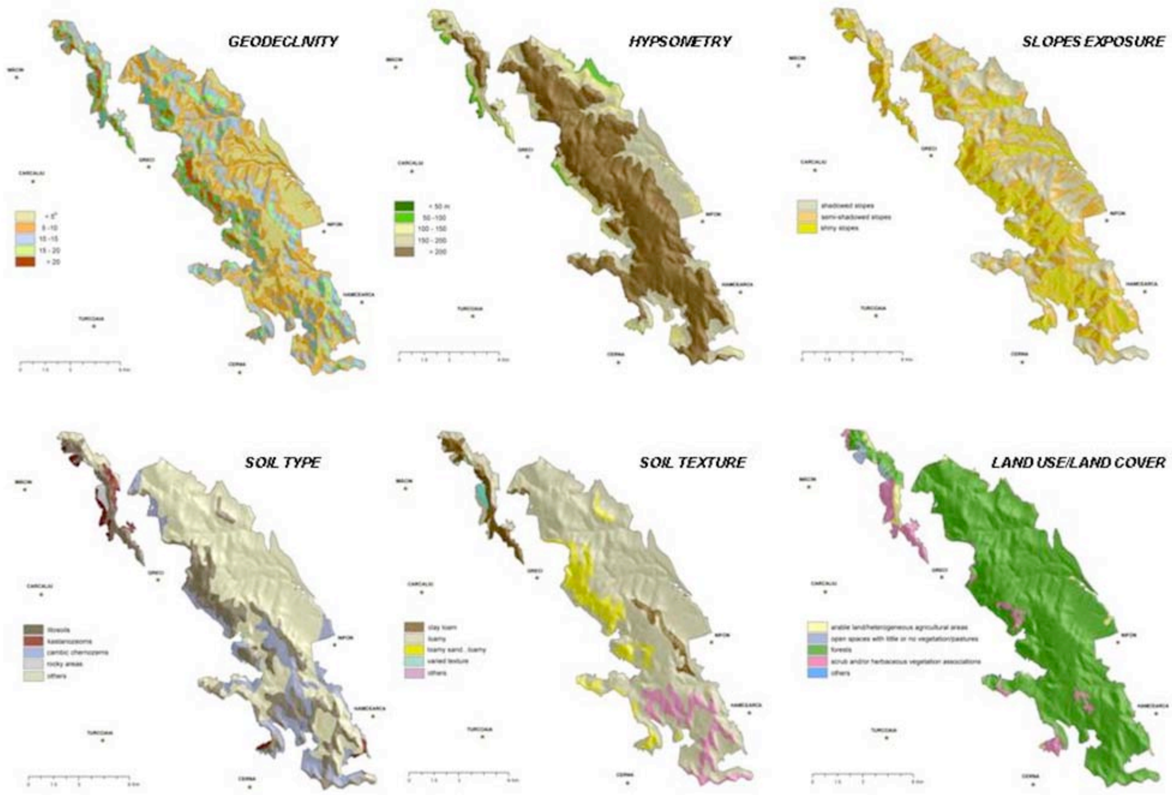


Figure 3.19. Local environmental driving forces' maps in the Măcin Mountains National Park

Species preference for rather shinny slopes (61.9%) explains its location at altitudes higher than 50 m (over 90%), with declivity between 5º and 20º (over 75%). In the studzy-area *Ailathus* was mainly found on litosoils (35.2%) and kastanozeoms (27.8%) with mainly loamy texture (44%). Concurrently, field researches have revealed species board development within scrub and/or herbaceous vegetation associations (63.5%).

Therefore, model validation has revealed that almost 70% of the *Ailanthus altissima* mapped areas overlap the areas with high and very high potential distribution and 25% of the mapped areas on medium potential distribution which points to a rather good confirmation of the used methodology (Table 3.17).

Table 17. *Ailanthus altissima* (mapped) depending on the classes of ITPS - podismod

Ailanthus altissima (mapped) (% of total surface)	ITPS – podismod classes
0.8	very low
4.3	low
25.0	medium
35.9	high
34.0	very high

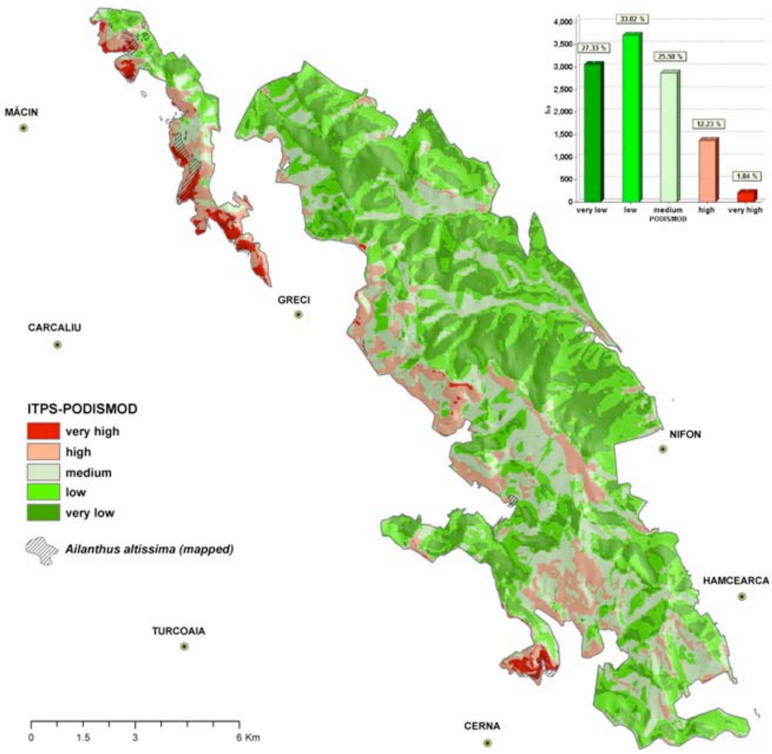


Figure 3.20. Potential distribution of *Ailanthus altissima* in the Măcin Mountains National Park (ITPS-podismod index)

Additionally, for *Ailanthus altissima* in the Măcin Mountains National Park the authors analysed **key biological indexes *(abundance, frequency, coverage*** and ***ecological significance)*** in eight selected test-areas mainly located in the western part of the Park area (e.g. Pricopanului Ridge) where the species was mainly found. According to biological index's classes (Table 3.18) this assessment revealed ceratin differences between the analyzed areas (Dumitrascu et al., 2013).

Therefore, the highest abundance values (Strigoaie Valley) are favoured by species' development in open areas (agricultural land use) and semi-sunny slopes' exposure while the lowest values are registered in the Carada Valley where the forest-covered areas doesn't represent a favourable habitat for *Ailanthus altissima*.

Table 3.18. Abundance – coverage scale according to Braun – Blanquet system (Cristea et al., 2004) and ecological significance index values

Class	Coverage interval (%)	Class value (%)
5	75-100	87.5
4	50-75	62.5
3	25-50	37.5
2	10-25	17.5
1	1-10	5.5

Ecological significance index (W)	
(%)	**Class**
W1 (0,1-1)	accidental
W2 (1-5)	accessory
W3 (5-10)	associate
W4 (10-20)	complementary
W5 >20	characteristic

In terms of frequency, Toader Mocanu and Izvoarele Valleys range fist due to quite reduced declivity and favourable soil texture which enabled the development of a wider variety of phytocenosis whereas Carada and Cozluk Valleys display the lowest rates due to reduced diversity of phytocenosis (Table 3.19).

Table 3.19. Biological indexes for *Ailanthus altissima* in the Măcin Mountains National Park

Test area	Abundance	Frequency	Coverage
La Chernoagă Valley	3	3	2
Toader Mocanu Valley	3	4	1
Izvoarele Valley	2	4	2
Strigoaie Valley	4	2	1
Largă Valley	3	3	3
Carabalu Valley	2	2	1
Carada Valley	1	1	2
Cozluk Valley	3	1	1

The coverage indicator shows more balanced values between the analysed test areas ranging between 1 (the lowest) in Toader Mocanu, Strigoaie, Carabalu and Cozluk Valleys and 3 (the highest) in Largă Valley.

The ecological significance of *Ailanthus altissima* stands for the difference between other two analysed indexes (frequency and abundance), referring to species' ecological value in the study-area. Taking into consideration that *Ailanthus* was mainly identified in the Pricopan Ridge, a geographical unit quite isolated located in the north-western part of the protected area, this index frames the species into the accidental and accessory categories (the highest value was registered in the Izvoarele Valley) (Figure 3.21).

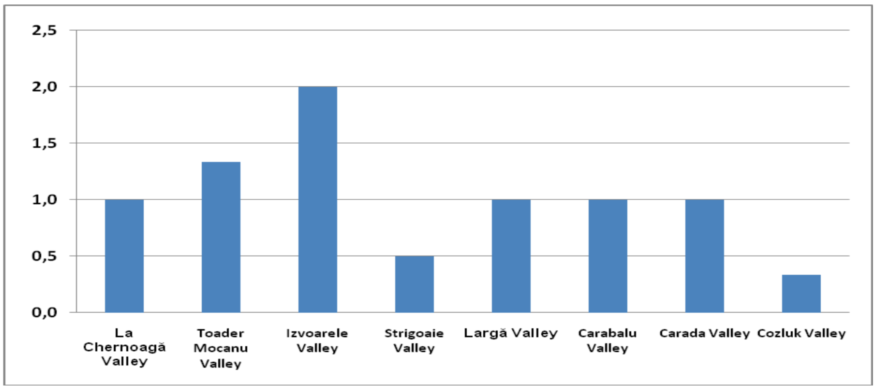


Figure 3.21. The ecological significance of *Ailanthus altissima* in Măcin Mountains National Park

Taking into account the ecological significance of this natural protected area (National Park - II IUCN category), the ecosystem's particularities (valuable floristic elements) and the massive transformation triggered by the human activity, the assessment of invasive terrestrial plant species becomes an essential task in providing proper management measures. The current study on the ITPS *Ailanthus altissima* in the Măcin Mountains National Park in relation to species' habitat particularities and key biological indicators aimed at providing a general outlook of this species in order to offer both relevant causal rationales and spatial analysis in relation to the specie requirements.

Therefore, establishing the relationship between species diversity and invasive success on one hand and the physical factors (both natural and human-induced) on the other would provide valuable future predictions through GIS-based modeling techniques. In the study-area, local authority's lack of knowledge on the potential danger of this species might jeopardise protected habitats. As a result, the outcomes of the present paper could constitute important basis for further assessments on *Ailanthus altissima* in terms of spreading potential aiming to develop the most appropriate eradication and control measures and integrate them into the Măcin Mountains National Park's Management Plan.

3.4.4. Maramureş Mountains Natural Park Case Study (IGAR)

Maramureş Mountains Natural Park overlaps the highest mountain massif located in the central part of the Carpathian Chain at the border of Romania with Ukraine. In 2005, the Maramureş Mountains were declared protected area, under the *Category V IUCN – Protected Landscape-Natural Park*, having as main characteristics for its designation: the specific landscape of mountains covered by forests alternating with alpine meadows, the presence of flora and fauna that is emblematic for the Carpathians within ecosystems which are still stable (forests, pastures, river bodies, lakes and marches, underground waters), the existence of natural habitats on large extension and the preservation of the traditional way of life (Năstase et al., 2010). The relief stands out as rounded summits rising up to 1800 – 1900 m, fragmented by deep valleys which had developed defile and depression sectors. The main rivers which drain this mountain unit are the Frumuşeaua, Ruscova, Vaser, Ţîsla and Vişeu out of which the latter had favoured the development of the most important settlements in the park area: Borşa and Vişeu de Sus.

The Park is administrated by National Forest Administration and has 133,354 hectares, representing the biggest park in the Romanian Carpathians. Moreover, 70 per cent of the Park area – except the inner-city of the localities within – has been up for Site of Community Importance, within the European Network – Nature 2000. Of all mammals listed in Appendix II of Directive 92/43/CEE of the European Council, in the park there can be identified all three species of large carnivores: wolf, bear and lynx ("Munţii Maramureşului" Natural Park – The Management Plan 2008).

Fallopia japonica (the Japanese knotweed*)*, also known as *Polygonum cuspidatum* or *Reynoutria japonica*) is a clonal, herbaceous, fast-growing perennial plant (Aguilera et al., 2010), largely occupying the riparian ecosystems and causing serious damages to native vegetation. The species is broadly regarded as one of the most invasive plant species in Europe, also listed by the World Conservation Union and FP6-DAISIE project as one of the top one hundred invasive species of global concern (Lowe et al., 2000 cited by Kabat et al., 2006; DAISIE 2005-2008; Lambdon et al., 2008). Knotweeds (the species which includes the genus *Fallopia*) are native to eastern Asia (Japan, Korea, northern China and Taiwan) (Pysek, 2006) whence they were introduced in the Unites States in the 1877s for ornamental purposes (Aguilera et al., 2010) and in Europe, starting with the Netherlands (1823) followed by Germany (1872), Poland (1882), United Kingdom (1886), Norway (1901) etc. (Alberternst and Böhmer 2006), thus becoming the most widespread and troublesome alien species on both continents (Weber, 2003 cited by Barney, 2006). Soon after, the species had become an aggressive invader to other countries such as Canada, the Czech Republic, Australia, New Zeeland, Belgium etc. (Kabat et al., 2006; Tiébré et al., 2007 and 2008; Aguilera et al., 2010; Moravcová et al., 2011; Sîrbu, 2011). Paradoxically, the Japanese knotweed become so popular as ornamental that, in 1847, it was awarded the "golden medal" by the Dutch Society of Agriculture and Horticulture as the most "interesting" species of the year (Bailey and Conolly, 2000 cited by Barney at al., 2006).

In Europe, *Fallopia* taxa includes: *Fallopia japonica var. japonica*, *F. japonica var. compacta*, *F. sachalinensis* (Bailey et al., 2007) and their hybrid (*F. xbohemica*) (Moravcová et al., 2011). They are strongly growing, herbaceous, gynodioecious, rhizomatous perennials and adventive plants which can grow up to 3 m in height (Kabat et al., 2006). *F. japonica* spreads by clonal and rhizomatous growth (stem fragments can produce buds and shoots giving rise to new plants), rapidly form a monoculture (Aguilera et al., 2010). Moreover, its invasive success may be enhanced by multiple hybridization events (Tiébré et al., 2007).

In Romania, *Fallopia japonica* was firstly introduced as an ornamental plant, in gardens and parks (especially botanical gardens). The species was quite poorly studied in the Romanian scientific literature although it was mentioned as subspontaneous species (escaped) for about seven decades, especially in Transylvania (Paucă, 1940; Ţopa, 1947 cited by Oprea, 2005; Sîrbu, 2011). Recent studies indicate its prevalence along rivers, roadsides, in ruderal places, etc. frequently in Transylvania, Maramureş, Crişana and Moldova and seldom in Banat, Oltenia and Wallachia (Sîrbu & Oprea, 2011).

Habitat requirements. The Japanese knotweed can usually tolerate a wide variety of environmental conditions ranging from high shade, high temperatures (even drought) to high salinity. In its native range, *Fallopia japonica* is a pioneer species on volcanic slopes and as invasive it invades disturbed habitats, tolerating a variety of soil structures and textures and pH levels, ranging from 3 to 8 (Pysek, 2006). It frequently occurs in riparian habitats (e.g. along river banks), but because of its invasive nature it also tolerates disturbed habitats, such as railroad tracks and roadsides (Forman & Kesseli, 2003; NB II, 2005). Other studies undertaken on *Fallopia japonica* also revealed its preference for: boundary walls in farmlands, urban non-industrial land, ruderal habitats, meadows, natural/semi-natural forests, roadways etc. (Tiébré et al., 2008). The species usually installs in open places, its growth and abundance being seriously affected by shading. The rhizomes are very resistant to low temperatures, thus permitting its survival in harsh climatic conditions (up to absolute minimum temperature of -30.2° C) (Barney et al., 2006).

Broad impacts. *Fallopia* taxa are now widely naturalized in many countries, thus becoming a threat to native ecosystems (Tiébré et al., 2008). It mainly occupies riparian areas, where it spreads rapidly, turning into dense monoculture structures provoking significant damages to river banks and related protected structures, paved surfaces, thus triggering significant impacts on native flora in terms of habitat and biodiversity loss (NB II, 2005; Barney at al. 2006). Consequently, through the huge amounts of rhizomes it generates, this invasive species is capable of penetrating and displacing foundations, walls, pavements, and drainage works (Beerling, 1991) causing flood hazards by increasing resistance to water flow and damaging flood prevention structures (Alberternst & Böhmer, 2006; Pysek, 2006). The species has a significant impact on soil cover through a greater mineral content, especially in terms of K and Mn, a decrease of bulk density and increase of organic matter, water content and nutrient levels (Pysek, 2006).

Spreading and habitat description of *Fallopia japonica* in the Maramureş Mountains Natural Park. In the Maramureş Mountains Natural Park the species was identified mainly in the western part, in the Vişeu river floodplain, but also in the central part – the Ruscova river floodplain and upstream to Repedea village (12 km from the confluence between the Ruscova and the Vişeu rivers) and on the Frumuşeaua and the Vaser rivers, near the confluence with the Vişeu. *Fallopia japonica* was also found close to the southern limit of the park area in Borşa town on Rodna Piedmont along the Pietroasa flow. The entire mapped surface totalises approx. 88 ha and indicates areas most invaded by this invasive species mainly on the river banks. Additionally, one can find compact areas with *Fallopia japonica* along the modernized roads, the railway connecting towns of Valea Vişeului and Vişeu de Jos and the flood protection dams along the Vişeu River (Figure 3.22).

In terms of phenology, the period of maximum development for the Japanese knotweed was identified between June and August. Moreover, the species proves to be highly resistant, especially to climatic hazards (drought, frost), mechanical and chemical treatments with herbicides.

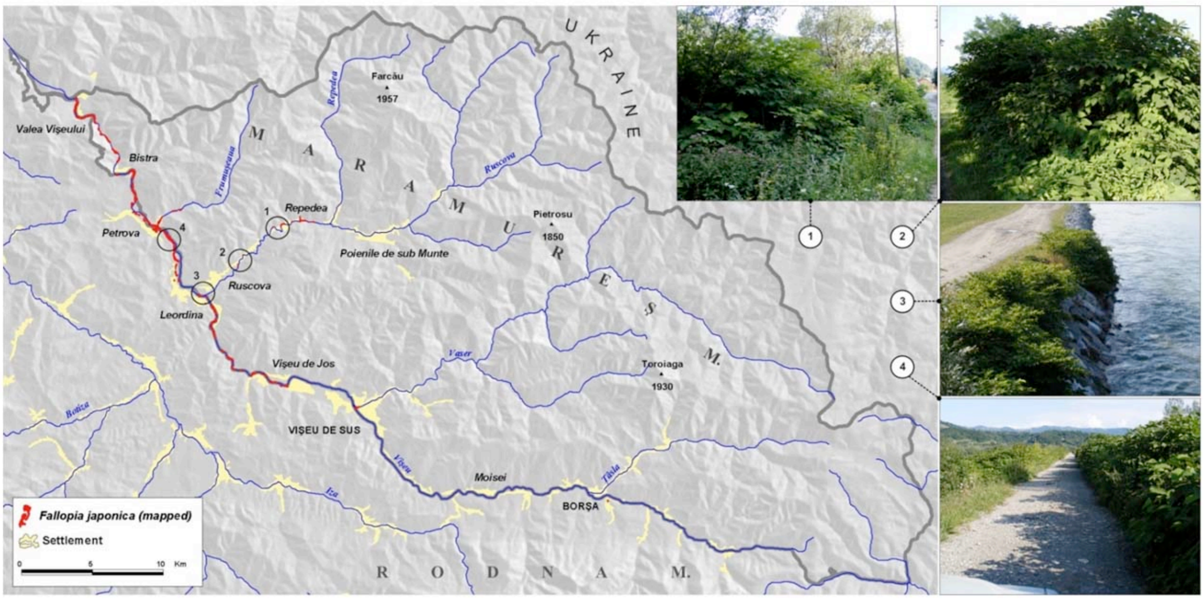


Figure 3.22. *Fallopia japonica* distribution in the Maramureş Mountains Natural Park (mapped areas)

In the study-area, during our preliminary field surveys it was noticed that *Fallopia japonica* individuals were often distributed near water bodies, preferring riverbanks, mainly the floodplain area at lower altitudes (under 500 m), open areas (free of coexisting species), tending to invade grasslands, croplands and even courtyards (e.g. the Vişeu river floodplain) and thus seriously affecting native vegetation (Figure 3.23).

Figure 3.23. *Fallopia japonica* specific habitat: near riverbeds (A), agricultural lands (B) and the tendency to parasitism (C) (photo: Gheorghe Kucsicsa)

The species' ***distribution*** in the mapped areas revealed a preference for habitats described by lower altitudes of well under 500 m (almost 100 per cent) and declivities of 0-5º (over 70 per cent) with no specific preference for slope exposure. In terms of lithology and soils, it develops mainly on gravels and sands (88 per cent) and alluvial and alluvial protosols soil types.

Table 3.20. Distribution of *Fallopia japonica* on the mapped areas in relation to the key environmental features

hypsometry (m)	ha	%	*declivity (º)*	ha	%	*slope exposure*	ha	%
300 – 400	68	77	0 – 3	58	66	shaded	48	55
400 – 500	19	22	3 – 5	5	6	semi-shaded	17	20
500 – 600	1	1	5 – 10	8	9	sunny	23	25
			> 10	17	19			

Lithology	ha	%	*soil type*	ha	%
gravels, sands	77	88	alluvial and alluvial protosols	88	100
sandstones, marls, conglomerates	8	9			
epimetamorphic schists	3	3			

air temperature (º) annual mean	ha	%	*precipitation amounts (mm) annual mean*	ha	%
8 – 9	69	78	700 – 800	67	76
6 – 8	19	22	800 – 1000	21	24

The broad climatic requirements of *Fallopia japonica* in the study-area are points to annual means of 8-9ºC for air temperature and 700-800 mm for precipitation amounts (Table 3.1).

Species morphology. In the study-area, the Japanese knotweed could reach a medium *height* of about 3-3.5 m. The *root* is very strong with a high penetrating capacity, thus producing significant damages to roads, buildings, agricultural lands etc., being able to develop well-built rhizomes; the *steam* is tubular, robust, and relatively upright build up by rhizomes (Figure 3.24).

The ***abundance***, estimated based on the number of steams, points to a high density of individuals on sq.m (e.g. up to 50 steams/sq.m. in the Ruscova river floodplain). It is widely recognized that this species forms dense patches, significantly reducing the diversity of native species, shading up other plants and slowing nutrient cycling (Barney et al., 2006; Aguilera et al., 2010).

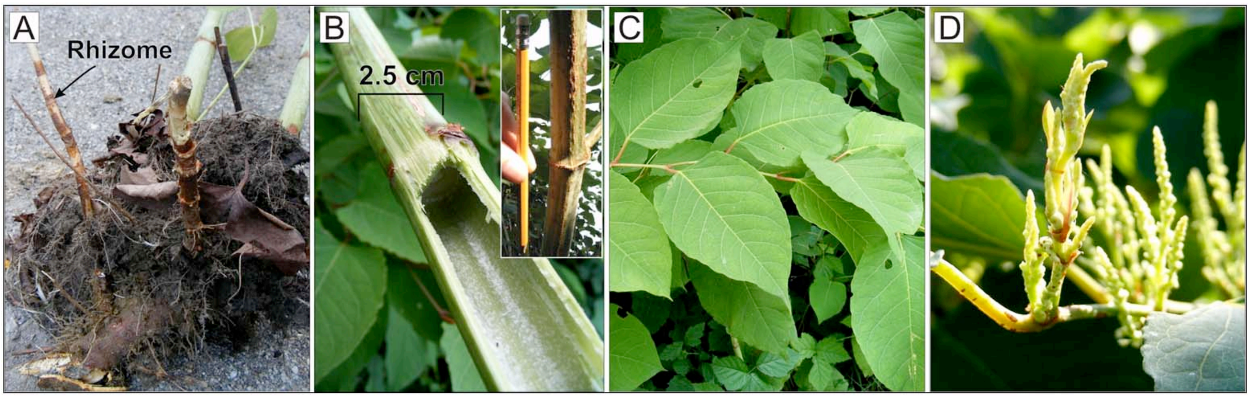


Figure 3.24. *Fallopia japonica* morphology: root (with rhizomes) (A), steam (B), leafs (C) and inflorescence (D) (photo: Gheorghe Kucsicsa)

The assessment of *Fallopia japonica* main parameters (distribution, abundance) and morphology in the Maramureş Mountains Natural Park reveal a high spreading and renewal potential of the species which turns it into a real threat to infrastructure, native flora and wildlife habitats, watercourses etc. Under the given circumstances, undertaking comprehensive studies on the species characteristics and distribution potential on one hand and developing eradication and control methods, on the other are highly recommended.

Table 3.21. PODISMOD *Fallopian japonica* – driving factors

factor	processed by	*w*	*r*	
Hipsometry ***(H)***	DEM (30 m)	1	< 400 m	5
			400 – 450 m	4
			450 – 500 m	3
			500 – 700 m	2
			> 700 m	1
Geodeclivity ***(G)***	DEM (30 m)	3	< 5º	5
			5 - 10º	4
			10 - 15º	3
			15 - 20º	2
			> 20º	1
Slope exposure ***(E)***	DEM (30 m)	2	flat	5
			shadowed slopes	4
			semi-shadowed slopes	3
			shiny slopes	2
Soil type ***(S)***	soil map (1:200 000)	5	Alluvial gleyed soils	5
			Alluvial soils	4
			Alluvial protosoils	3
			Albic luvisoils	2
			others	1
Soil texture ***(St)***	soil map (1:200 000)	3	Various textures	5
			Loamy sand	4
			Loamy sand… clay loam	3
			Loamy sand…loam	2
			others	1
Distance to rivers ***(Dr)***	orthophotoplans (1:5 000)	5	< 50 m	5
			50 - 100	4
			100 - 150	3
			150 - 200	2
			> 200	1
Land cover ***(Lc)***	orthophotoplans (1:5 000)	4	built-up areas, areas with ligneous vegetation	1
			open spaces	5

where ***w*** = weigh; ***r*** = rank

Based on the complex assessment of the ITPS *Fallopia japonica* and the assigned ***rank (r)*** and ***weight (w)*** according to the analyzed driving forces, the final potential distribution classes ranked between 27 and 115 (Table 3.22).

$$\mathbf{5(S_r + Dr_r) + 4Lc_r + 3(G_r + St_r) + 2E_r + 1H_r}$$

Table 3.22. ITPS - podismod classes

interval	ITPS - podismod	% of surface
< 45	very low	3.9
45 – 63	Low	29.1
64 – 81	Medium	33.5
82 – 99	High	23.8
> 99	very high	9.7

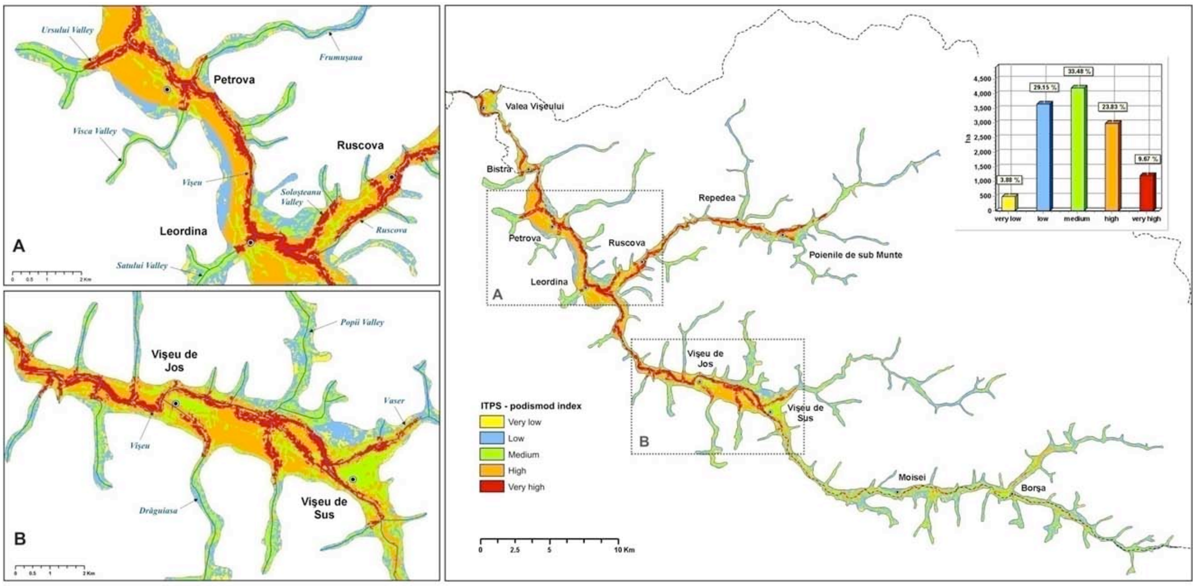


Figure 3.25. Potential distribution of *Fallopia japonica* in the Maramureş Mountains Natural Park (ITPS-podismod index)

Discussions. Knowing the high invasive potential of *Fallopia* taxa due to its high genotypic diversity which determines its ability to adapt and differentiate into new environments (Bailey et al., 2007; Tiébré et al., 2007) a complex assessment of this species in protected areas is highly required. The current study on the ITPS in the Romanian protected areas with a special focus on *Fallopia japonica* in the Maramureş Mountains Natural Park – both V IUCN category and Natura 2000 site - in relation to the species' habitat requirements and key environmental features is essential in identifying and defining the most significant causal and spatial relationships. Therefore, establishing the relationship between species diversity and invasive success on one hand and the physical extrinsic factors (environmental features) on the other (Shea & Chesson, 2002) would provide valuable future predictions through GIS-based modelling techniques.

Fallopia japonica is an extremely invasive adventive species whose management and control are difficult and expensive. Due to its rapid invasive potential, high capacity for regeneration and tolerance to different environmental factors, it has an increased impact, both ecological and economic. Its spread in floodplains can cause damages to indigenous habitats and plant communities (especially the *Salix* and *Alnus* associations which have an important role in flood protection and control). Moreover, due to its presence along the access routes (mainly modernized), the species constitutes a "threat" to the pavements and railway embankments due to its strong adventive roots. It can also cause damages to river banks, aiming to protect localities against flooding, or to land cover/land use by invading arable lands or grasslands located near or along river valleys.

Therefore, in the study-area local authority's lack of knowledge on the potential danger of this species might jeopardise both natural habitats and population safety, especially in the flood-prone areas, such as the Vişeu, the Repedea and the Frumuşeaua floodplains. As a result, the outcomes of the present paper could constitute an important starting point for further assessments on *Fallopia japonica* in terms of spreading potential and dynamics aiming to develop and integrate the most appropriate eradication and control measures in the Maramureş Mountains Natural Park's Management Plan.

3.4.5. Mureş Floodplain Natural Park Case Study (IGAR)

Mureş Floodplain Natural Park is overlapping the lower part of Mureş river and occupies the embanked enclosure of the Mureş River between the city of Arad and the state border with Hungary (Bălteanu et al., 2006) totalizing a surface area of 17,166 ha. The protected area, established in 2004, hosts specific wetland habitats of plant and animal species of great scientific value within four nature reserves: *Prundu Mare–Pecica, Igriş Isles, Insula Mare Cenad* and *Cenad Forest* (Bălteanu et al., 2006). The Mureş Floodplain Natural Park is a typical wetland ecosystem with running and still waters, alluvial forests as well as an important place for nesting and passage for about 200 bird species, many of them of international importance (Dumitraşcu et al., 2010). In the Mureş Floodplain Natural Park, *Amorpha fruticosa* prefers forest roads and forest glades (especially north to Mureş river), as well as pastures and bounds area located in the lower lands.

For this study-area the authors have improved the methodology described in the methodological part of this chapter. Therefore, the rank *(R)* of each key driving factor was made using the bivariate analysis. The bivariate analysis is one of the simplest forms of the quantitative statistical analysis which takes into consideration the relationship between two variables, in our case between the ITPS (dependent variable) and its driving factors (independents variables) (Kucsisca et al., 2013).

The result is given by the relationship between the (mapped) surface covered with ITPS and the analysed driving factor. For example: the relationship between ITPS and soil texture, between ITPS and distance to rives, between ITPS and land use etc. The result is given by the relationship between the (mapped) surface covered with ITPS and the analysed driving factor. As a consequence, the ***rank*** was obtained as a result of the percentage of species on each driving force's classes as shown in the graphs below (Figures 3.26, 3.27, 3.28, 3.29, 3.30 and 3.31).

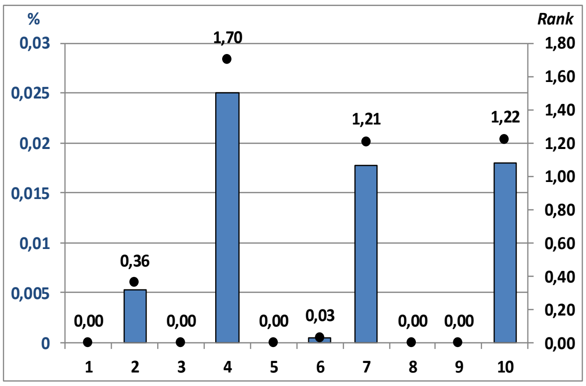


Figure 3.26. The *Soil type Rank* (reclassified into 10 classes) and *Amorpha fruticosa* distribution (species' % on each soil type class)

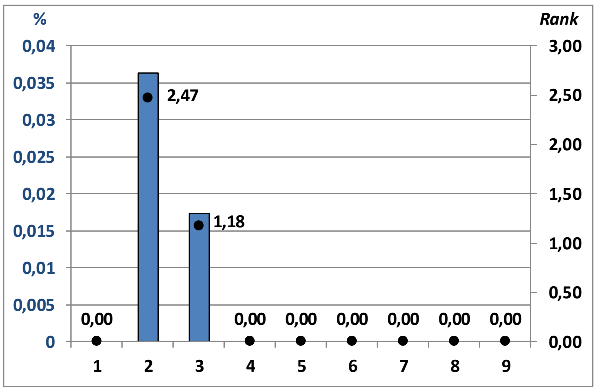


Figure 3.27. The *Soil texture Rank* and *Amorpha fruticosa* distribution (species' % on each soil texture class)

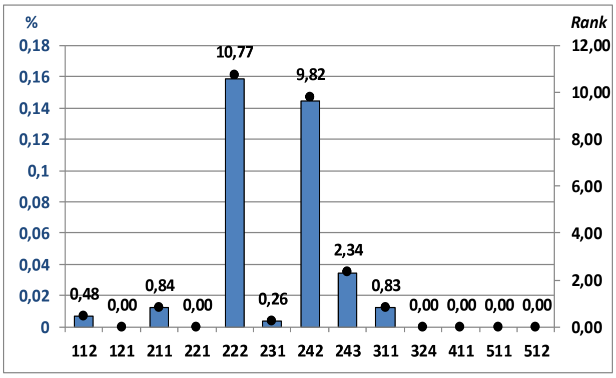


Figure 3.28. The *Land use/cover Rank* and *Amorpha fruticosa* distribution (species' % on each LUC class)

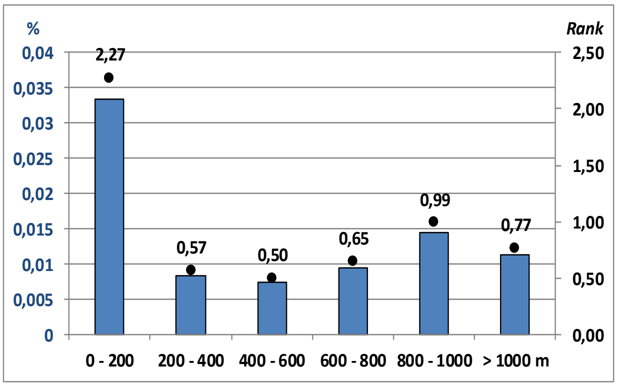


Figure 3.29. The *Waters buffer Rank* and *Amorpha fruticosa* distribution (species' % on each waters buffers class)

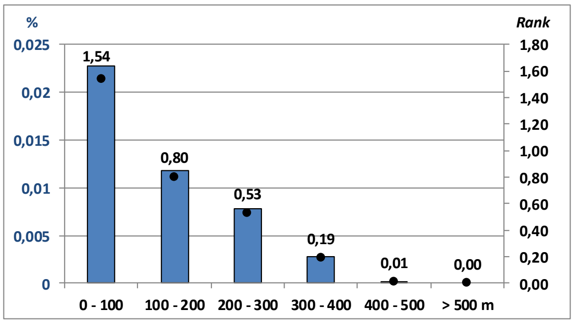


Figure 3.30. The *Forest roads Rank* and *Amorpha fruticosa* distribution (species' % on each forest roads buffers class)

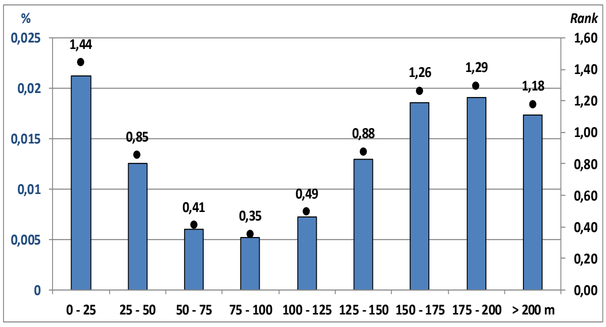


Figure 3.31. The *Fragmentation Rank and Amorpha fruticosa* distribution (species' % on each fragmentation class)

In order to apply the potential distribution model for *Amorpha fruticosa* in the Mureş Floodplain Natural Park six driving factors were selected: soil type, soil texture, land use/cover, distance to water bodies, distance to forest and agricultural roads, and fragmentation areas (Figures 3.32 and 3.33). The latter refer to forest and woodland areas fragmentation by forest roads, to glades and cultivated lands. Dependent on all these categories the authors had created a buffer.

Each driving factor was evaluated on a 1 to 3 scale, higher values being assigned to the most important ones in ITPS distribution. In Table 3.23 are represented the weight (w) of selected driving forces of *Amorphafruticosa*in the Mureş Floodplain Natural Park.

Table 3.23. The *w* (weigh) value assigned to the key drivers of *Amorpha fruticosa* in the Mureş Floodplain Natural Park

Driving forces	Soil type	Soil texture	Water bodies buffer	Land use/land cover	Forest roads buffer	Fragmentation of forests and scrubs
weigh	3	2	2	2	1	2

The **PODISMOD index.** The ITPS-podismod map emphasizes ***high*** (39.5%) and ***very high*** (8.5%) potential distribution of *Amorpha fruticosa* close to Mureş River and in the vicinity of Park's area in the central-northern and south-eastern parts. In these areas the predominant soils are alluvial protosoils and erodisoils with a varied texture. The forest covered areas are extremely fragmented, especially by the forest roads. ***Medium*** values of ITPS-podismod cover the largest surfaces of the Park area (42.1%), mainly displayed in the southern part of Mureş River, where arable lands and pastures prevail. The main soil types are alluvial and cambic chernozems with loamy sand and clay loam textures. ***Low*** and ***very low*** ITPS-podismod values cover limited areas of Parks' area (9.9%), especially in the eastern half where forest cover and agricultural areas prevail.

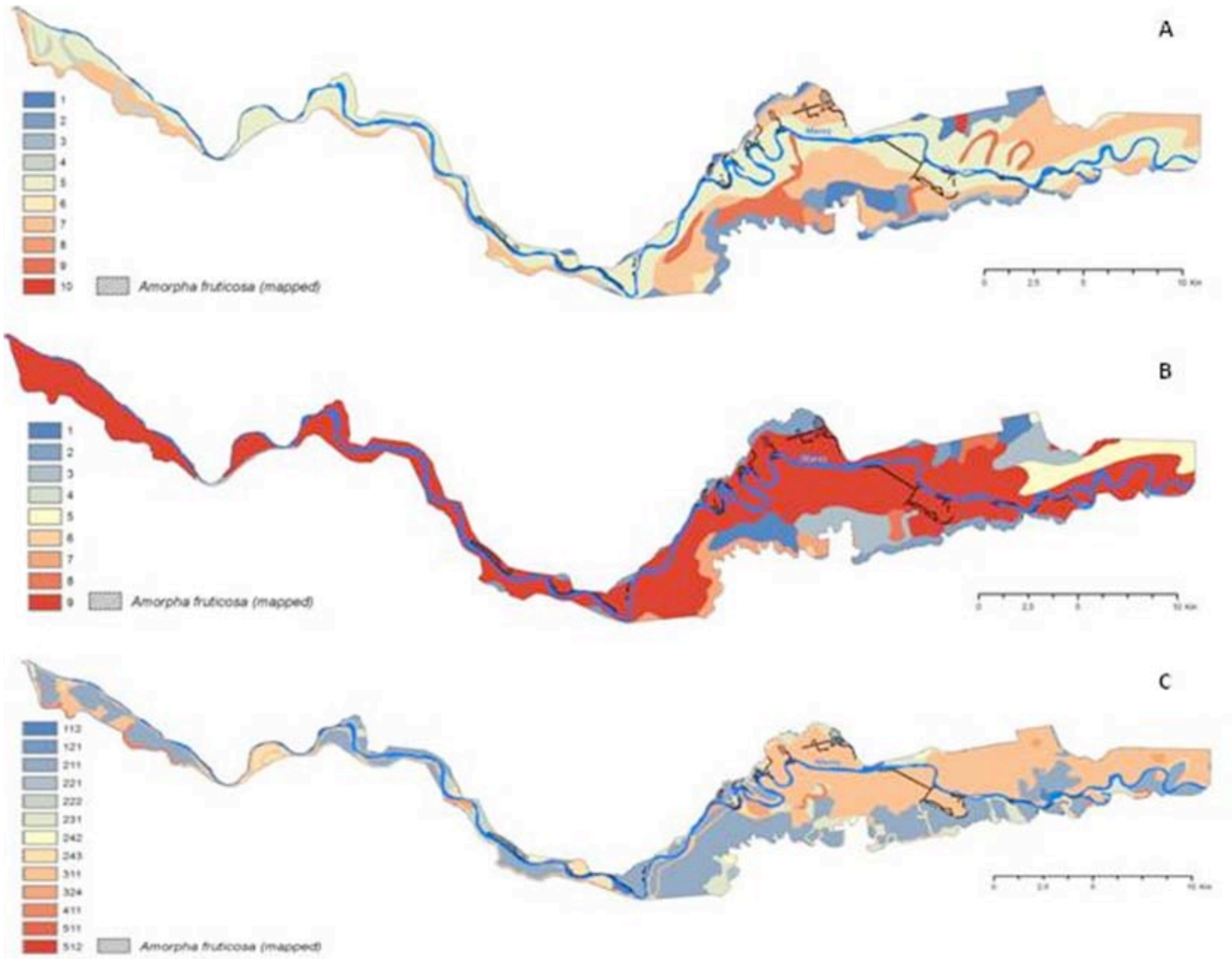


Figure 3.32. *Amorpha fruticosa*'s potential distribution depending on soil type - reclassified (A), soil texture – reclassified (B) and land use/land cover - Corine Land Cover, level 3 (C)

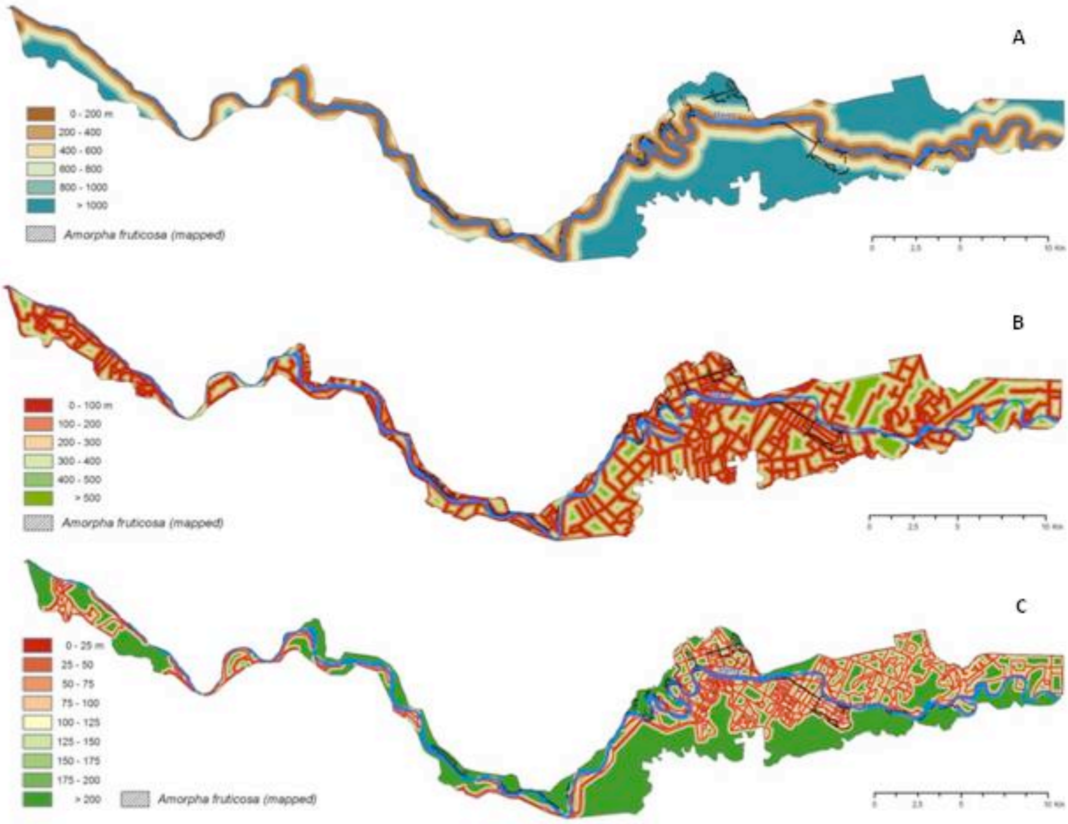


Figure 3.33. *Amorpha fruticosa*'s potential distribution depending on distance to water bodies (A), forest and agricultural roads (B) and fragmentation buffers (C)

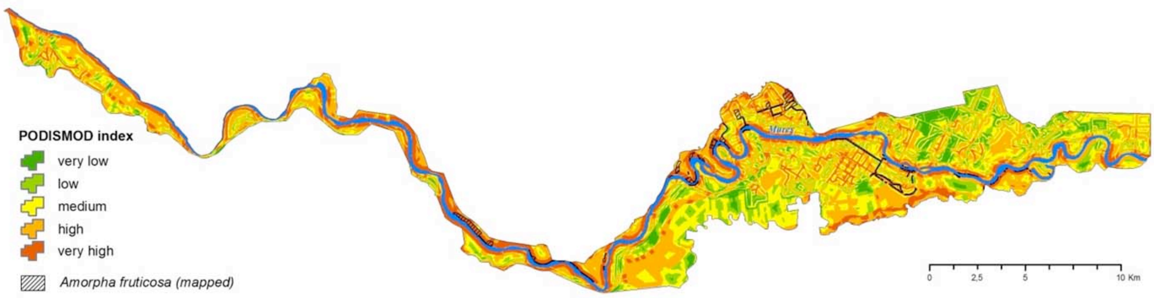


Figure 3.34. Potential distribution of *Amorpha fruticosa* in the Mureş Floodplain Natural Park (ITPS-podismod index)

The accomplishment of the ITPS potential distribution model is given by the ***prediction rate*** which provides relative values of nearly 50% (***average* = 47%**). Te prediction rate was computed as the intersection between the pixels representing the areas with mapped *Amorpha fruticosa* and the obtained ITPS-podismod classes. The produced graphical image outlines the resulted percent on the OY axis (Figure 3.35). Therefore, the prediction rate points to ***very low* = 94%, *low* = 1%, *medium* = 30%, *high* = 89% and *very high* = 20% values.**

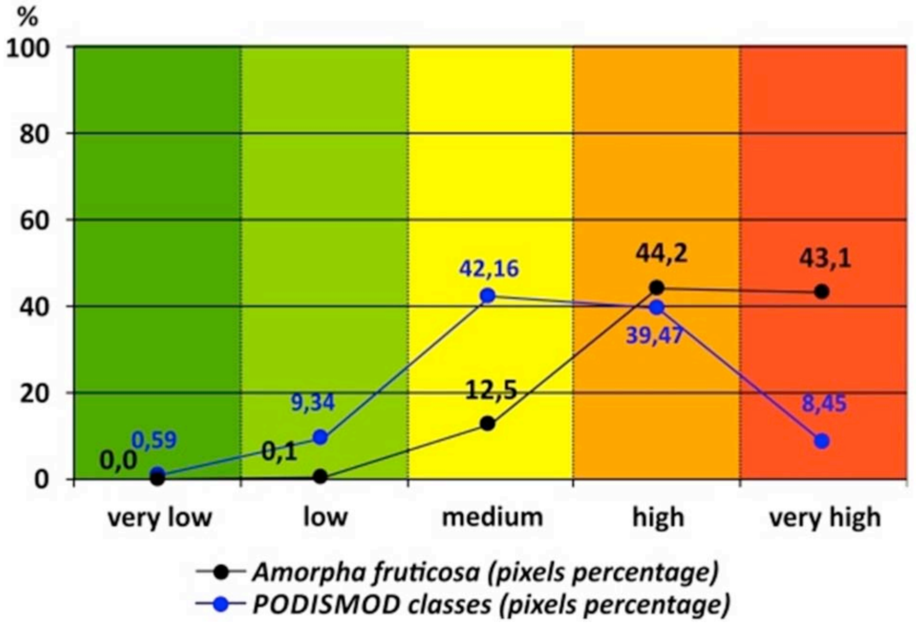


Figure 3.35. The prediction rate of *Amorpha fruticosa* ITPS-podismod in the Mureş Floodplain Natural Park

The average values of nearly 50% display very good results for the high ITPS-podismod class where the prediction rate is of 89% and very poor results for the low ITPS-podismod class (1%). The outcome could be improved by an increased number of mapping areas with *Amorpha fruticosa* as well as by using more recent and accurate thematic maps for the analyzed driving factors.

3.5. Key indicators in assessing ITPS in the Romanian Protected Areas

3.5.1. Case-study: *Amorpha fruticosa* ITPS in three wetland areas: Danube Delta Biosphere Reserve, Comana Natural Park and Lunca Muresului Natural Park (IGAR + DDNI)

Recent studies consider *Amorpha fruticosa* as one of the worst invaders, especially in wetland habitats, endangering *Salix* spp. associations (EUNIS code F9.12) (Doroftei ,2009). The species proved a high capacity of widening its spreading area, thus being adapted to all types of habitats such as: along river banks (poplar or willow galleries, almond willow-osier scrubs), unvegetated or sparsely vegetated shores, water-fringing reedbeds, riverine and lakeshore scrubs etc. (Anastasiu at al., 2007), metal-contaminated soils, tailing ponds, fertilized terrains (Li, 2006; Seo et al., 2008; Marian et al., 2010; Xiang, 2011) etc.

Methods and data. The current study is trying to asses *Amorpha fruticosa* ITPS in the following Romanian wetland protected areas: Danube Delta Biosphere Reserve, Comana Natural Park and Mureş Floodplain Natural Park. The authors used scientific cross-referencing, field surveys (using G.P.S device, sample taking, monitoring of the key areas) and GIS mapping in order to able to compute species spreading area.

The surface areas chosen for the comparative research regarding the phenology data were of 10 m² for pastures and reed-covered areas and of 100 m² for the forest and brushwood communities. The quantitative biological indices taken into consideration for the current approach (coverage, abundance, frequency and ecological significance) were computed in several test-areas in the analysed case-studies.

Species' coverage was undertaken based on the real and absolute coverage whose values vary depending on the phyto-individual habitus of species. According to Braun-Blanquet the estimation system of coverage includes 5 levels: 1 – weak, under 1/20 of sample surface; 2 – between 1/20 and 1/4 of sample surface; 3 - between 1/4 and 1/2 of sample surface; 4 - between 1/2 and 3/4 of sample surface; 5 - between 3/4 and 4/4 of the test area (Table 3.24).

Table 3.24. Abundance – coverage scale according to Braun – Blanquet system (Cristea et al., 2004)

Class	Coverage interval (%)	Class value (%)
5	75-100	87.5
4	50-75	62.5
3	25-50	37.5
2	10-25	17.5
1	1-10	5.5

Species' abundance was carried out based on Braun-Blanquet methodology which considers a visual scale: 1-very rare; 2-rare; 3-less abundant; 4-abundant; 5-very abundant individuals.

Species' frequency was computed based on Raunkiaer (1934) method indicating the number of phytocenosis in which the analysed species was identified (Cristea et al., 2004): F = n/N x 100, in which: n = number of surveys in which the species is present; N = total number of surveys). According to the frequency value of *Ailanthus altissima,* four categories can be distinguished: F1 – accidental species (1 – 25% of relevees); F2 – accessories species (25.1 – 50% of relevees); F3 – characteristic species (50.1 – 75% of relevees); F4 – frequent characteristic species (75.1 – 100% of relevees).

Additionally, in order to identify species' position within the phytocenosis**,** the **ecologic signification** index was computed as a relationship between frequency and abundance (Table 3.25).

Thus, based on this in-depth analysis the authors and relate biological indicators with relevant key natural and human-induced driving forces.

Table 3.25. The ecological significance index values

Ecological significance index (W)	
(%)	**Class**
W1 (0,1-1)	accidental
W2 (1-5)	accessory
W3 (5-10)	associate
W4 (10-20)	complementary
W5 >20	characteristic

Results and discussions. *Amorpha fruticosa* can be easily adapted to different types of natural and disturbed habitats but its preference for wetlands can be an explanation for its wide spread in the **Danube Delta Biosphere Reserve** (Anastasiu & Negrean, 2005; Anastasiu et al., 2008; Dihoru, 2004; Doroftei, 2009). The detailed investigation undertaken in five pilot areas (*Pardina Agricultural Polder, Caraorman sand dunes, Şontea – Fortuna Depression, Matiţa – Merhei lake complex and Dunăvăţ – Dranov fishing pond*) for which relevant key biological indicators were computed revealed species preference for the fluvial sand banks along the main Danube branches and fluvial-marine sand banks as well as the flooded areas (Figure 3.36).

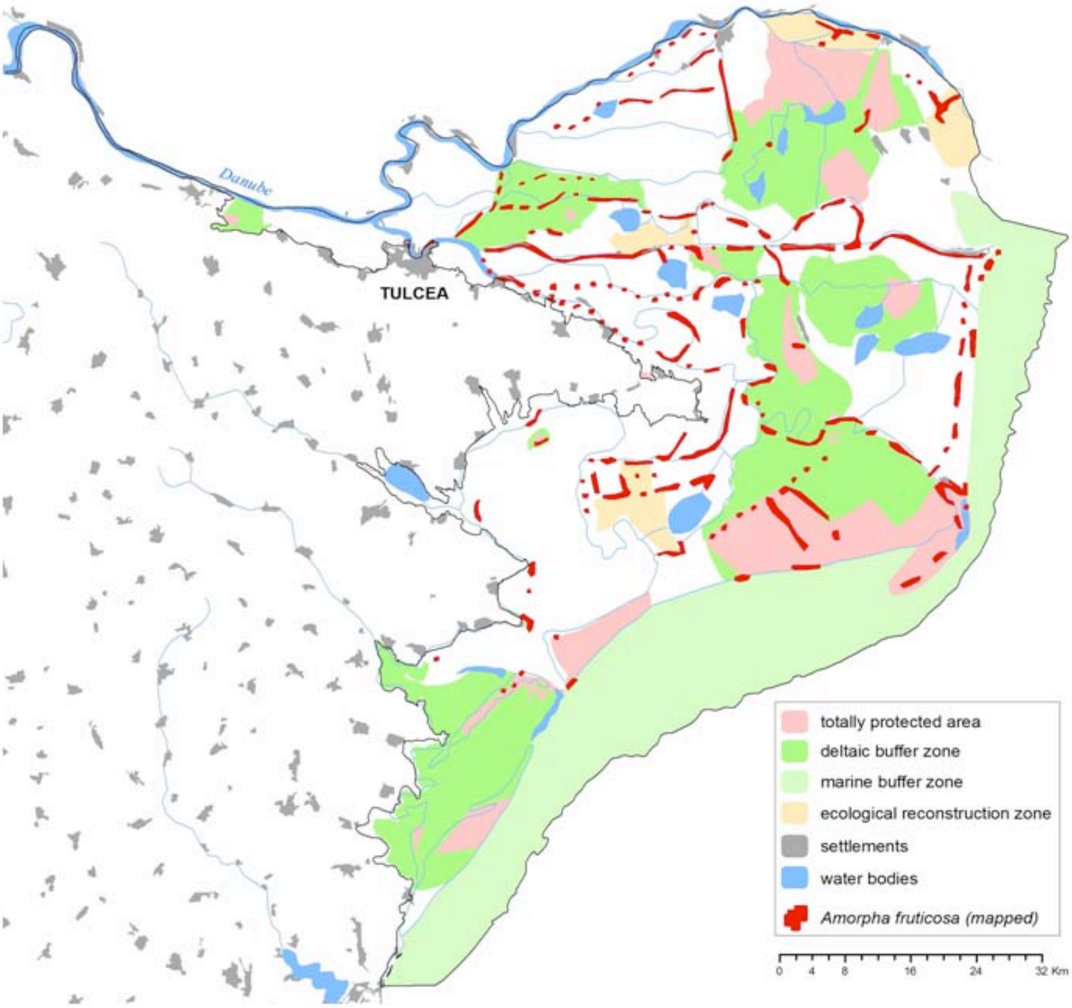


Figure 3.36. The distribution of *Amorpha fruticosa* in the Danube Delta Biosphere Reserve

Thus, highest coverage, frequency and abundance values were registered in the Dunăvăt – Dranov fishing pond and Şontea – Fortuna Depression where wetland habitats prevail (Figure 3.37).

In terms of habitat types, *Amorpha* populates in this protected area: 92A0 *Salix alba* and *Populus alba* galleries; 92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*); 91E0*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*AlnoPadion*, *Alnion incanae*, *Salicion albae*); 91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis*, *U. minor*, *Fraxinus excelsior* or *F. angustifolia* along the great rivers (*Ulmenion minoris*).

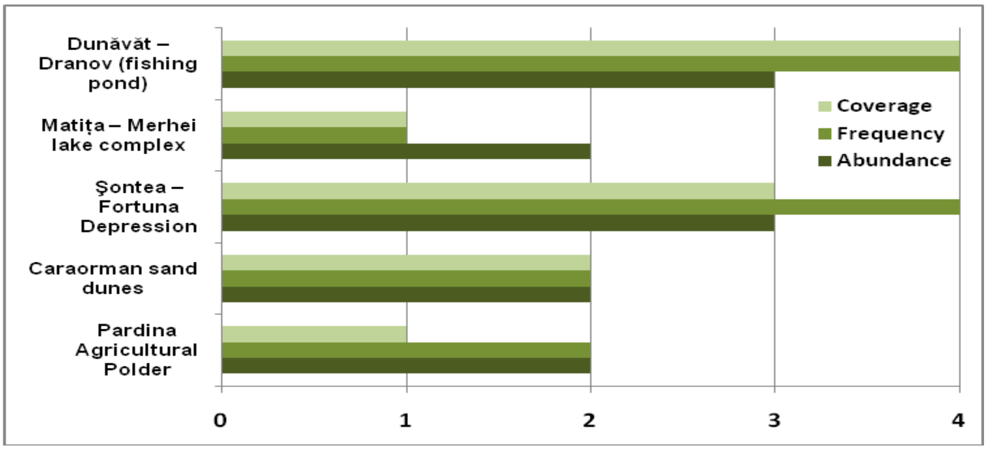


Figure 3.37. Key biological indices for *Amorpha fruticosa* in Danube Delta Biosphere Reserve

Besides riparian habitats the species also inhabits dune and steppe-like habitats such as: 2160 Dunes with *Hippophaë rhamnoides*; 92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*); 62C0* Ponto-Sarmatic steppes as well as 3270 Rivers with muddy banks with *Chenopodium rubri* pp and Bidention vegetation.

In the **Comana Natural Park** *Amorpha fruticosa* prove to have a higher dominance in the surroundings of wetlands (margins of Comana Lake), river channels and alongside the transport network, especially on the spoiled soils located next to the non-electrificated railroad as well in the outskirts of forests (Figure 3.38).

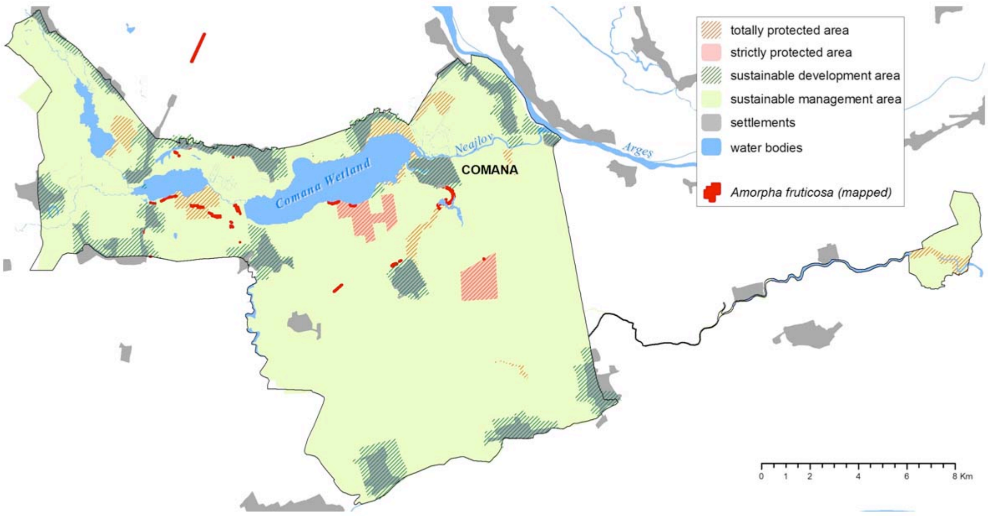


Figure 3.38. The distribution of *Amorpha fruticosa* in the Comana Natural Park

In accordance with the identified preferred habitats, the authors selected seven pilot areas for a detailed analysis: *Crucea de Piatră Village, the northern side of Călugăreni village, southern part of Comana Village (along the rail road), Budeni Lake (south side shore), north of Vlad Ţepeş Village, Fântânele Forest along Neajlov River and south of Mihai Bravu Village* (Figure 3.39).

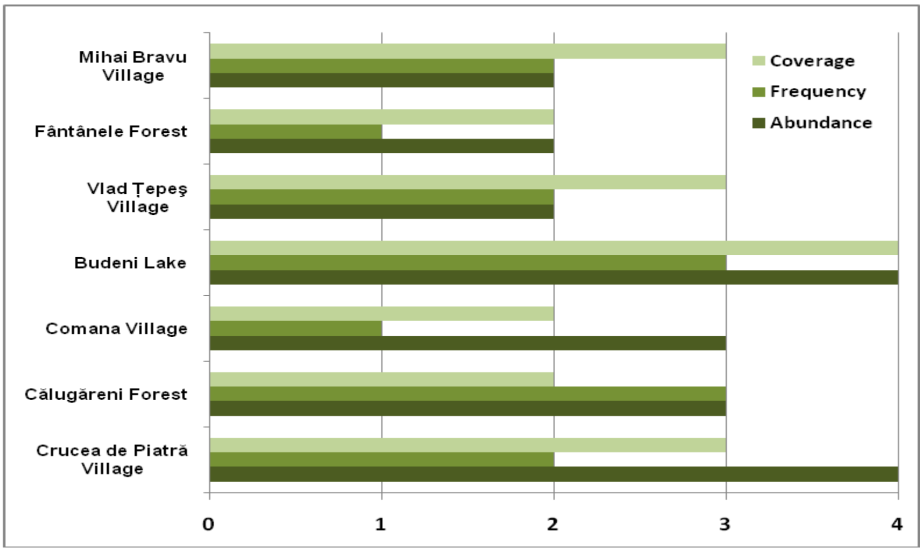


Figure 3.39. Key biological indices for *Amorpha fruticosa* in Comana Natural Park

The monitoring of the areas and the results of the computed biological indicators revealed higher values for abundance and coverage in the Crucea de Piatra Village and Budeni Lake and frequency in Călugăreni Forest and Budeni Lake, thus showing species' preference for riparian and edge habitats such as: 92A0 *Salix alba* and *Populus alba* galleries; 92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*); 91E0*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno Padion, Alnion incanae, Salicion albae*).

In the **Mureş Floodplain Natural Park,** *Amorpha fruticosa* have a preference for forest roads and forest glades (especially north to Mureş river), as well as pastures and edges of arable lands (Figure 3.40). This endorsed the authors to select as main key areas for analysis the following: *Zădăreni Village* along the banks of the Mureş River; *Popinilor Forest*; *Raţa-Vaida Forest* (Pecica Village); *Bezdin Forest* (Sânpetru German village); riparian habitats, meadows and modified vegetation in *Şeitin Village* and *Igriş Village*.

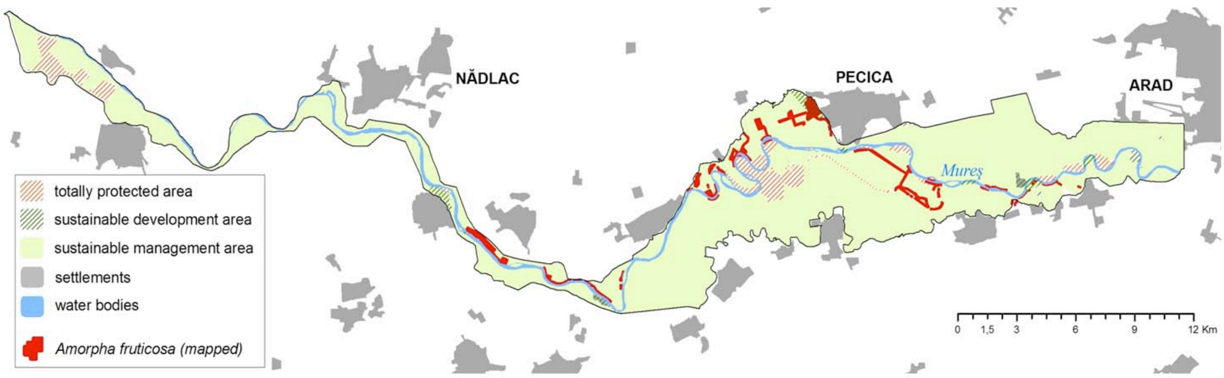


Figure 3.40. The distribution of *Amorpha fruticosa* in the Mureş Floodplain Natural Park

The computed indices for the selected key areas show a higher development of the analysed species in Zădăreni Village and Popinilor and Raţa-Vaida Forests, mainly preferring riparian habitats: 92A0 *Salix alba* and *Populus alba* galleries; 92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*); 91E0*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*AlnoPadion, Alnion incanae, Salicion albae*); 91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis, U. minor, Fraxinus excelsior* or *F. angustifolia* along the great rivers (*Ulmenion minoris*); 3270 Rivers with muddy banks with *Chenopodium rubri* pp and *Bidention* vegetation (Grigorescu et al., 2012; Dumitraşcu et al., 2013).

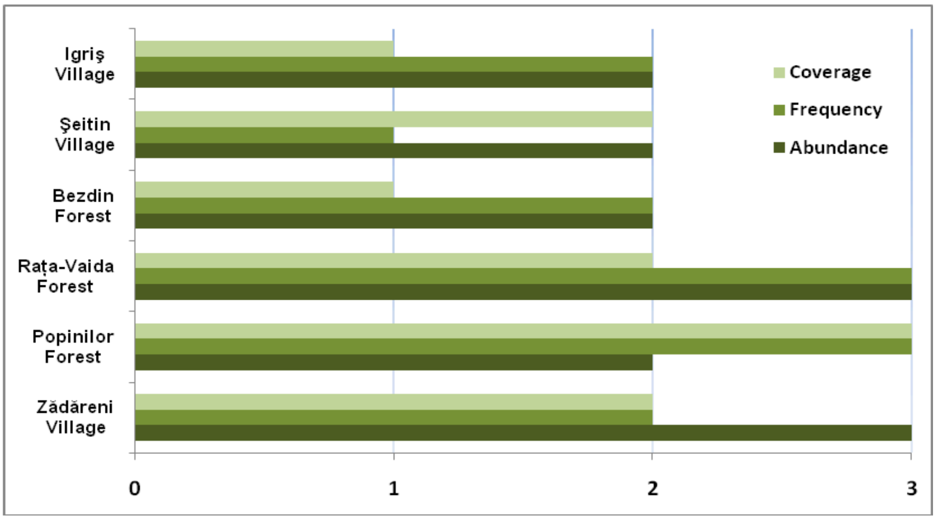


Figure 3.41. Key biological indices for *Amorpha fruticosa* in Mureş Floodplain Natural Park

The investigation of ITPS *Amorpha fruticosa* in the selected case-studies has slight differences in terms of the analysed biological indicators. Thus, Danube Delta Biosphere Reserve shows higher abundance and coverage values while the frequency seems lower as compared to the other two study-areas.

On the other hand, Comana Natural Park displays higher frequency rates while in the case of Mures Floodplain Natural Park the values for the three indicators show rather even value (Figure 3.42).

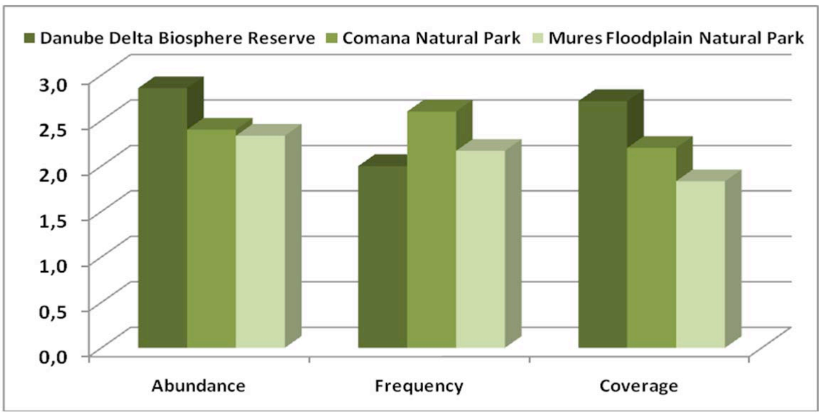


Figure 3.42. Average class values of the key biological indicators for *Amorpha fruticosa* in the studied areas

Consequently, the **ecological significance** considered as the relationship between frequency and abundance, shows values from between 2 and 12 for the analysed key areas in the Danube Delta Biosphere Reserve and Comana Natural Park and rates which does not exceed 9 units in the Mureş Floodplain Natural Park (Grigorescu et al., 2012; Dumitraşcu et al., 2013).

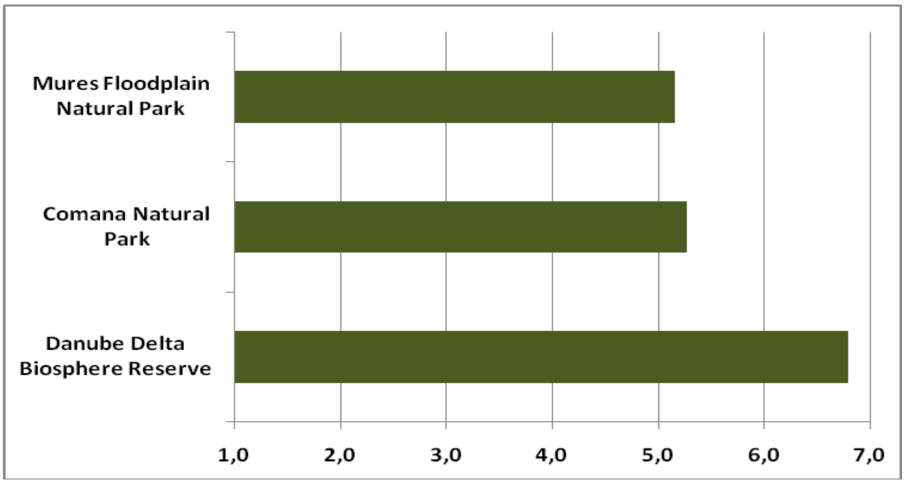


Figure 3.43. Average ecological significance for *Amorpha fruticosa* in the studied areas

The average values points Danube Delta Biosphere Reserve fist in terms of ecological significance of *Amorpha fruticosa* followed by Comana Natural Park and Lunca Muresului. In all studied areas, the species is considered (W3) associate species (Figure 3.43).

The landscapes of protected areas were transformed, over the last years, by human activities through tourism, deforestation, overgrazing, overexploitation of natural resources etc. All of these have led to the replacement of natural forest and pasture ecosystems with secondary meadow and scrub associations, thus affecting the floristic structure and composition. Considering the strong relationship between biological invaders and their key driving forces of change, assessing species dynamics, impact and spreading potential becomes an important task in identifying natural habitats' pressures and threats. The identification of both natural and human-induced disturbances and relating them to in-depth biological (through detailed observations, computing biological indicators etc.) and geographical assessment (GIS-based investigations, integrated spatial analysis etc.) could support sustainable management strategies to prevent the invasion of species in natural protected areas.

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List of abbreviations

AC	Adaptive Capacity
ARCH	AutoRegressive Conditional Heteroskedastic
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AU	Assessment Unit
BCR	Biological Contamination Rate
CBD	Convention on Biological Diversity
CGIAR-CSI	Consortium for Spatial Information
DAISIE	EU-FP6 project *Delivering Alien Invasive Species In Europe*
DLCM	Discrete Linear Cascade Model
DPSIR	Driving forces–Pressures–State–Impact–Response framework
DS	Decision Support Module
DSS	Decision Support System
DTM	Digital Terrain Model
E	Exposure
EASIN	European Alien Species Information Network
EEA	European Environmental Agency
EFAS	European Flood Alert System
EPS	Ensemble Prediction Systems
ERNAIS	European Research and Management Network on Aquatic Invasive Species
EU	European Union
EUNIS	European Nature Information System
ESRI	Environmental Systems Research Institute
EWS	Early Warning System
F	Flood index
FMM	Flood Mapping Model
GDEM	Global Digital Elevation Model
GEV	General Extreme Value
GIS	Geographic Information System
GPD	Generalised Pareto Distribution
GUI	Graphical User Interface
HM	Hydrodynamic Model
IAS	Invasive Alien Species
ICPDR	International Commission for the Protection of the Danube River
IMDC	International Marine & Dredging Consultants
ISSG	Invasive Species Specialist Group
ITPS	Terrestrial Invasive Plant Species
IUCN	International Union for the Conservation of Nature

JRC	Joint Research Centre
MCMC	Markov Chain Monte Carlo
MODIS	Moderate Resolution Imaging Spectroradiometer
MODSIS	Monitoring and Detection System for Invasive Species
NASA	National Aeronautics and Space Administration
NBII	National Biological Information Infrastructure
OFFWS	Operational Flood Forecast and Warning System
PDM	Probability Distributed Model
PODISMOD	POtential DIStribution MODel
REABIC	Regional Euro-Asian Biological Invasions Centre
SBC	Site-specific Biological Contamination index
SCI	Site of Community Importance
SoFlIm	Social Flood Impact
Sp	Susceptibility
SPA	Special Protected Area
SRTM	Shuttle Radar Topography Mission
SSC	Species Survival Commission
RR	Rainfall Runoff
RU	Relative Air Humidity
UNEP/WCMS	United Nations Environment Programme /World Conservation Monitoring Centre
V	Vulnerability
WFD	Water Framework Directive