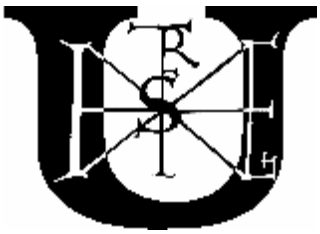

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Economical aspects of flood-protection

Ph.D. thesis

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INTRODUCTION

„…Water is still Mighty!" – Petőfi Sándor

Not only Hungary but many other countries have recently been experiencing an increasing number of natural catastrophes. Mankind has been stuck by a variety of disasters such as floods, bores and earthquakes causing serious damages in common and private properties as well. The losses that cannot be expressed in numerical values are even more devastating: losses in human lives, damage in protected natural values and historical sites.

Although prevention would be the most effective way of protection against natural disasters, many times the inherent cost seem unbearably high and it becomes clear only after the catastrophe happened that it would have been much worthier to invest into prevention than spend on restoration. In many instance restoration is not realizable, the losses in human lives cannot be compensated afterwards. Natural catastrophe is a complex conception, Hungary is most vulnerable to water related phenomena.

23% of Hungary is alluvial plain of which 8% is flood plain. Flood plain serves for safe flood conveyance (it is flooded annually or even more frequently), but the alluvial plain is an area that has to be protected, because valuable assets accumulated here since river regulation started, therefore the protection of these areas is of high priority. In European comparison the Netherlands suffers from the same unfavourable conditions.

Characteristics of the endangered territories in Hungary:

- *2,5 million people in 700 settlements* are vulnerable to floods,
- 1/3 of the *arable soil* is located here, and 1,8 million hectares of valuable agricultural land where, the annual turn-out could exceed 200 Billion Ft,
- 32% of rail roads and 15% of high ways run along here, with a value of 270 billion Ft,
- More than 2.000 *industrial facilities* are found here, with a value of 540 billion Ft, generating 1.143 billion Ft annually,
- The annual gross product of the area is 1.540 billion Ft, 25% of the national gross product.

There are several flood prevention methods in practise, one of the most effective is building dikes. Following the construction, the surface of the dikes cannot stay uncovered, because the waves, the precipitation, the wind and other environmental factors derogate the protective capacity of the dikes. The most widely applied biological slope-protection is the sod, which is, besides fitting better into the natural environment is cheaper than other revetment materials and its visual affect

is far more aesthetical. (Later on the structure of husbandry changed and the adjunct demand disappeared.)

The topic I chose is quite complex; it is based on floods and the relevant damages. I focus on the investment thrift analysis of sod revetment investments on dikes, therefore my main goals are the following:

- Designation of a territory for economical assessments which is proven to be highly vulnerable to floods;
- Composition assessment of the sod revetment on the pilot area, comparison of the relevant literature and the practical experiences;
- Assessment of the role of the different sod revetments during flooding;
- Estimation of the value of assets put in risk;
- Estimation of social benefits;
- The assessment of the dikes and the diked areas as alternative utilization direction for extra incomes.

Sod revetment and management is a simple investment, the question is, whether it is worth implementing and maintaining, whether a well preserved sod revetment serves such a role in flood protection that spending money on it is beneficial?

The summary of my most important hypoteses is the following:

- flood risk is reducible by sod revetment;
- The value of risk related to diked areas, empirically qualifies as endangered areas is in compliance with the estimations;
- The economical return of sod investments has to be calculated by modelling, taking the risk change as yield into consideration;
- To assess the investment thrift of flood protection facilities, the classical investment thrift model has to be augmented by directly non numerable yield factors.

MATERIAL AND METHOD

I started my research with studying the relevant literature. Besides reviewing the generic and technical literature I also had the opportunity to get an insight into the database of the Water Directorates. The Internet database was also an important source. In addition, I performed botanical surveys twice a year – in spring and in fall – on the pilot area.

My goal was to evaluate the texts, build a database and analyze the already existing databases.

When designating an area for sod revetment assessment, the primer task is the definition of the state of endangerment. Certain parts of my assessment were carried out by using multivariate mathematical analysis (MINITAB programme), since I had to evaluate the coherence of factors whose relevance is hardly definable unequivocally, and it is revealed only after the assessment which factors are significant in the given problem. I choose the main-component analysis and discriminatory analysis.

Multivariate econometric methods

It often comes along in our daily life that we cannot compare things, events only because we do not find a common feature on which the comparison could be based on.
Furthermore, it is not always obvious which features play a significant role in the assessment and what their interactions, relations are. Using multivariate models might assist in the solution.

The two most determinant Hungarian water-courses are the Danube and the Tisza. The Hungarian length of the Danube is 417 km, of which 142 km is Slovakian-Hungarian border line. The Hungarian length of the Tisza is 596 km, of which 52 km is border-river. The total length of the Hungarian river network is 2 417 km. The average discharge of rivers entering the country is 114 km^3/year, the ones' leaving the county is 120 km^3/year, so the total water discharge generated within the country is only 6 km^3/year. Considering the total population of the country, this amount is very low in European comparison, but because of the basin-nature of the country, the amount of water running through the country per person is the highest is the world. Respecting water, Hungary is a transit country, the quality and quantity of our water resources are highly dependent on measurements taken in other neighbouring countries. 52% of the country is vulnerable to water damages and ¼ is threatened by flood. The damage caused by a one-time flooding in a smaller diked area would reach at least 5-6 billion Ft, and in larger diked areas it could reach up to 30-40, or even 150 billion Ft. I used multivariate methods – based on modelling – to designate the impended diked areas.

Main component analysis

The main component analysis is an assessment method that unfolds the important interactions between original features. It involves artificially created variants that are related to a well defined group of original features, and it is supposable that due to being determined by the main component, there is a strong relation between the original features within the group. We group the variants based on their correlation and represent the major main components (two or three) in space. This representation helps to group the individuals, their relations and similarities based on the location of equivalent points.

Discriminatory analysis

It's main purpose is to explain the diversity of the differences between different groups according to certain variants. The application of the method includes the formation of groups and the definition of variants that play a decisive role in the factor assessment. It is revealed during the application of the method whether taking the given factors into consideration results the right classification.

Sod – the Balázs square method

There are several methods used for sod-component analysis and yield evaluation. Mowing is a frequently used method (mowing of a few m^2, measuring of the grass and selection of components), there is the animal-thermometric method (used mainly for yield estimation) and the square method, which I also chose to apply.
The Balázs Ferenc square method is well applicable for species- or type-specification of a given area and for yield estimation. The process enables the quantitative and qualitative analysis of the sod revetment. The pilot area is designated randomly by surrounding a 2m*2 m square. The qualitative analysis aims to list all species of the flora found within the square, attempting completeness. I carried out my survey on the Middle-Tisza district using parcels with the required range, which were chosen to be representative. It was my intention to give a general description on the condition of the surrounding area.

Analysing the total diked area of the river Tisza would have been an unaccomplishable task, therefore I designated pilot areas on the territory of Water Directorate chosen by multivariate methods. These are the diked areas of the Middle-Tisza District Environment and Water Directorate. I had to keep in mind to have the diked areas located close to each other and also to designate areas which were:

- Sod testing areas – Körös-zug (2.86);
- Neighbouring to sod testing areas – Cibakháza (2.85);
- Inundation would cause the most serious damage – Szolnok (2.50);
- Neighbouring to the most vulnerable area – Jánoshida (2.49).

Dates of the surveys:
- 26. May 2003. – before mowing
- 16. October 2003. – 2 weeks after mowing
- 27. April 2004. – before mowing
- 27. October 2004. – 4 weeks after mowing
- 03. May 2005. – before mowing

SWOT analysis

When taking the different possibilities into consideration, environment and market assessment has to be carried out, the micro- and macro-environment has to be observed separately.

The assessment method is called SWOT analysis:

Strengths = S
Weaknesses = W
Opportunities = O
Threats = T

The SWOT analysis is always an individual process. The definition of strengths and weaknesses contributes to an internal assessment, while the examination of opportunities and threats focuses on macro-environment-related issues. I used this method in my research to evaluate the alternative flood-plain utilization, with special attention to the economical evaluation of beef cattle breeding.

Investment and thrift

Due to the special features of the investment, the traditional investment thrift analysis cannot be used, but the amended and completed nett present value index is appropriate for the analysis of sod revetment. It is related to another alternative way of utilization – energy forests-, so I examined the currently existing energy systems based on carbon, hydrocarbon and nuclear basis. Having examined the demands and available sources, it was proven, that the alternative resource research and the related thrift analysis is essential. I calculated the thrift of alternative resources by using nett present value (NPV) index.
Investment evaluation requires the yield of investment, which is calculated by the cash-flow. In my research the traditional cash-flow had to be amended.

Modelling

The purpose of the modelling is the transformation of real systems for the assessment of logical coherences. The changes induced in the model are moulded

to the reality. Based on the results, recommendations could be made on the original system.

Sensitivity assessment

It is worth carrying out sensitivity assessment during traditional investment thrift analysis, because it reveals, how certain factors – or more of them – affect the thrift. The differences compared to the realistic value could be either favourable or unfavourable, therefore we should calculate with optimistic or pessimistic evaluations. The degree of difference is determined depending on the conditions. Factors of the assessment would be the days of inundation, the measure of inundation, the extent of the inundated area, etc.

Monte Carlo simulation

Investments may have several outcomes, their risk is evaluated by sensitivity assessments. We can study the effect of changes in values of certain variables by sensitivity assessments. Even if we evaluate a project in several circumstances, the changes of only a limited number of variables predominates. Monte Carlo simulation is, on the other hand, a tool, which evaluated all the possible combinations. With Monte Carlo simulation we can study the total distribution of the project outcomes.

CONCLUSIONS, RECOMMENDATIONS

Hungary's natural, economical and geographical features specify the significance of the economical assets alongside the natural river courses. The protection systems of territories with high density of population have to satisfy at least two functions: firstly they have to provide protection against extreme water levels, secondly they have to be endemic. These criterions are best fulfilled by sod-covered dikes. An extended network of dikes was built in Hungary during the last one and a half century, and nowadays their establishment is rather a technical problem than an economical question. I emphasize two aspects of dikes in the essay: on one part the economical aspects of sod revetment establishment and maintenance – I was attempting to reveal the connection between the quality of the sod revetment and the protection capacity of the dike, which affects the flood risk as well - on the other part I did my research on the characteristics of the different investment thrift methods of flood protection dike establishment. I summarize my most important conclusions with respect to these aspects.

An important topic of the research is the assessment of the sod revetment. The method of the research was a botanical survey (extent of the covered area, components of the sod, ratio of the useful grass), which proved the importance of maintenance of sod revetment on the dikes. Counter to expectations, the old sod revetment is in better condition than the recently established, which would be explained by the fact, that maintenance resources were formerly available continuously, contributing to the strengthening of the sod revetment. The tenuity and weediness of the newly established sod revetment (2000) is resulted by neglect caused by the lack of financial sources. Significant differences were experienced in the coverage, the new seeding is 20-50% less beneficial than the old one. The ratio of useful grass is also 30-40% less in the revetment established in 2000. We can conclude, that the coverage and ratio of useful grass, and through this the protection capacity of the dike relate, since the different sod revetments fulfil their functions with different effectiveness, resulting an increase in cost and damage risk.

We have to state the question, whether it is beneficial to maintain the sod revetment, do they provide extra safety during floods?

Based on my research on the Lower-Tisza section, I came to the conclusion, that sod mix is compiled in accordance with a uniform principle, I did not find major differences in the components, any the less, these areas are maintained by different Directorates. It is a matter of regret, that uniformity was experienced in weediness as well, Amorpha fruticosa and Cirsium are two invasive species expanding in the area.

Before completing thrift analysis related to the establishment and maintenance of sod revetment, I analyzed the traditional investment thrift methods. I conclude, that these methods cannot be applied without modifications, since the largest incomes of flood investments are the lack of damage and the risked assets, whose value is difficult to be calculated, therefore the traditional methods had to be amplified. I compensated this deficiency by building a model, but before doing so, I looked over the water level and frequency data of a gauging station on the grass plot. I selected the Tiszaug gauging station and the nature justified my research. The confluence of the river Tisza and the river Körös at Tiszaug is the spot where the protection work is carried out with the greatest effort.
The peeking periods of the spring and fall flood waves were defined by analysing a longer time period (1990-2005). It was unequivocally revealed, that the tendency of higher water levels has been increasing in the last years. It shows how important it is to keep the dikes in well condition.

The investment and maintenance costs were empirically definable, but the calculation of incomes was a more difficult task.
In case of traditional grass plots, the income is defined by the value of grass out-turn. This method is in practice, but harvesting from the slopes requires special tools, therefore is very complicated. The structural changes in husbandry in the late 1980's induced a decline in demands.
The most important income factor is the virtual yield value estimated from the value of risked assets, in case the damage did not happen. There are accepted methods and processes to determine the social, industrial and agricultural assets, but the estimation of values that are difficult to numerate (human lives, natural values) requires a complex approach.

Several alternatives were examined during the modelling. There were restrictive specifications even in the application of the method used by Hungarian water experts – conscious protection of valuable areas.
Following the structuring of the modified cash-flow, the mathematical contexts used for indirect yield estimation demanded a special approach. Simplifying specifications had to be applied to assist the calculation of values (the distribution of risked values on the flood plain is even).
There has been a several decade long debate among scientists on the evaluation of human lives. According to a general opinion, it equals to the GDP per one active person, an approach I also applied.
The income comprises of the benefit of the alternative utilization, or the cost of protection, which were reduced due to the proper maintenance of sod revetment.

Running the model proves that the return rate of dike establishment under general conditions is about 65-70%. Examining areas with different economical development proves that only the low intensity areas do not produce yield, areas with already an average development state are worth investing in.

I got at flood plain examination by searching for further income sources. Almost 2% of the country's territory is flood plain, an area with such extent is worth dealing with. This area is responsible for the unobstructed conveyance of floods, it derives from its nature, that it could be covered by water at basically any time of the year, and the law regulates the activities that could be carried out on this area (only at own risk).

In case of energetic utilization we cannot calculate with significant incomes. The present energetic situation and the social attitude disable the plantation of beneficial energy forests. It would be worth dealing with this issue only in the event of larger governmental funding or increased price of briquette and pellet. At the same time we find several forests on the flood plain serving flood protection purposes, whose plantation and maintenance is obligatory. Exchanging these for energy forests – in accordance with the relevant regulations – might be a solution and turn out to be a profitable investment.

Our accession to the European Union opens several possibilities. The EU supports the beef-cattle and sheep breeding, for which the flood plain offers extremely favourable conditions. Sheep gazing could even be carried out on the slopes: they would leave a closed and short grass-layer behind. Supported by EU co-funding, extensive husbandry of these animals would be a profitable activity, and by integrating these activities into sod maintenance technology, cost would be reduced, resulting direct incomes.

NEW SCIENTIFIC RESULTS

Through my research I came to the following new and inventive results:

- There is a proven relation between the proper and regular maintenance of the sod revetment and the sod coverage of the dikes (resulting better protection capacity);
- I built a new model for thrift analysis of those investments, where one side (in this case the incomes) contains elements that are difficult to calculate with , and within this process I established the following :
  - Modified cash-flow of the establishment and maintenance of sod covered dikes;
  - Created mathematical relations for the calculation and estimation of direct yield;
- Studying the alternative utilizations I came to the conclusion, that energy forestation is not beneficial for energetic utilization, but if plantations are related to the obligatory forests serving protection purposes – keeping their original functions -, the investment could be thrifty;
- Flood plain utilization could be expanded by the requisition of EU sources.

Table 1. summarizes the hypoteses of my research, the methods of affirmation and disaffirmation and the results I received by applying these methods. I managed to scientifically affirm all of the hypoteses.

Table 1. – Summary of hypothesis

Hypothesis	Assessment	Result
Flood risk is reducible by sod revetment.	Botanical surveys on the pilot areas.	Maintained sod revetment results serried grass and more intense coverage with higher amount of useful components.
The value of risk related to diked areas empirically qualified as endangered areas, is in compliance with the estimations	Multivariate econometric methods (discriminatory analysis and main component analysis).	Flood risk is justified to be higher in diked areas empirically qualifies as endangered areas.
The economical return of sod investments has to be calculated by modelling, taking the risk change as yield into consideration	Review of the available investment thrift methods, unfolding their problems.	Most of the incomes cannot be directly numerated, theoretical approach had to be used.
To assess the investment thrift of flood protection facilities, the classical investment thrift model has to be augmented by directly non numerable yield factors	Modelling.	The adequate model proved the necessity of investment in the majority of the analysed cases.

Source: own compilation

Finally I can conclude – and nature provides justification- that sod-covered dikes have inestimable benefit in flood conveyance. The establishing and maintenance of a serried and unbroken sod revetment is an investment, whose necessity is justified not only by experiences but by thrift calculations.
The importance of flood protection is undoubted, so every applicable method and progress has to be taken into consideration that could improve the flood safety of the population and their assets.

SUMMARY

For the past few decades a great many natural disasters have caused a lot of damages everywhere worldwide, not only in the respects of the property of the inhabitants, industry and agriculture, but in the values of nature and nation, or in the lives of people as well.

Natural disasters envelop a complex conception. In respect of Hungary the examination of dangers in relation to waters is the most significant question. Since the 19th century conscious and inter naturally acknowledged work has been going on, in the course of which banks proved to be one of the most effective protection systems against floods. The surface of the dams after the construction is covered with law in the interest of more effective water draining. I examined the economic relations of the establishment and maintenance of these law surfaces.

The established theme itself is complex, water management – flood protection included – touches you're the lawn management and, of course, the examinations of the economy of investment as well, from the point of view of economy.

I started my researches by studying the suitable literature. Border lining the circle of the necessary literature proved to be difficult owing to the varieties of the theme. Besides the professional libraries, home and foreign literature and journals, I had the opportunity to study the materials of water management and section engineering, too.

Within the main topics of water management, gradually approaching the Carpathian-basin, the water management of Hungary and the history of regulating our rivers were the bases of my researches.

In respects of lawn management the history of planting grass, with including, the history of grass planting of water-management establishments meant the starting point.

Of the view point of economy the investment-profitability has various and thoroughly processed literature, in the respect of the investment examined by me, however, the establishment of model became indispensable towards the examination of the effects of difficult, numerable factors.

My applied methods besides modelling were various variable econometric examinations (discriminate and main component analysis). Besides this botanical lawn recording was prepared with the help of econometrical methods in the chosen greatly endangered from the point of view of flood protection areas. During my

researches about alternative incomes of flood plain I needed to use investment-profitability indexes and SWOT-analysis.

As a result I stated that those law surfaces which are in good condition and thick help safety passing of flood. The reason for this is that when we systematically cultivate the grass its condition will be better.

I also analysed the data of water levels and I found that in the last one and a half decades the trend of water lines increased. The higher and higher flood cause bigger load for damages.

I made a model and in this I used the Net Present Value as a basis. Because the collateral incomes are dominants it is difficult to determinate in numerical value the incomes so I needed to adapt and complete the method that I used.

To evolve the real actualities I also needed to alter the traditionally used cash-flow and I had to account of some limiting condition. I had to estimate these values and I needed to empirically approximate the measure of risk. After finishing the calculus in the model, I realized that establishment of lawn-surfaces were refunded not only in high risk causes (where this investment is essential) but when the area has average hazard.

I also did some research into alternative utilizations of flood plains which are important if we need more income. I stated that – beside numberless existing possibilities (arable, meadow, etc.) – we may choose new opportunities. One of this is the energetic development (energy grass or forest). It is known that today this type of using is not cost-effective, but with minimal changes in conditions we can make it profitable.

In all I can state the water-management needs conscious, concreted work and competence. Traditionally we can't say that this function is profitable but after analysing circumstances and conditions it is truth we have the possibility to do some economic research in this discipline.

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