laplant brief

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MANAGEMENT OF LANDSCAPE AND WATER RESOURCES IN THE CZECH REPUBLIC

LESSONS LEARNT FROM THE PROJECT LAPLANT

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Recommendations and strategies

The LaPlaNt project was aimed at improving public as well as expert stakeholders' awareness of hydrological and environmental aspects of agricultural land management. The further project goal was to show the potential for increasing related ecosystem services in diverse modes of different land use and management in relation to the dynamics of natural factors. By means of educational and popularising tools, the functioning and roles of different landscape components were explained based on their impact on hydrologic cycle, water quality and quantity, soil erosion, floods, droughts, and related ecosystem reactions from the perspective of water and nutrient balances as well as biodiversity.

In this brochure, there are shortly described some results as well as recommendations from LaPlaNt related with sustainable agricultural land use and management. Such land management, which enhances water balance in landscape, protects soil against erosion, does not deteriorate water quality and biodiverstity and maintains satisfactory crop yields.

The results and recommendations are addressed to farmers, state officers and teachers as well as to general public in order to harmonize different aims and expectations of these stakeholders associated with agricultural land management and living in rural landscape.

This chapter provides a brief summary and page reference with detailed information of the major findings and recommendations based on results from the project LaPlaNt.

Stakeholder participation

pg. 6 - 7

- The results of the performed survey show the students' awareness of the relations between agriculture and the environment as fairly good, however the need for strengthening environmental education at a policy-making level still lasts

pg. 12 - 14

- It is recommended to further strengthen stakeholder awareness and involvement as this will lead to a more targeted research and its better uptake and thus also result in a better water resource management.

Based on the findings mentioned in chapter “stakeholder engagement” it is recommended to encourage:

pg. 12 - 14

- Individual as well as common workshops and other training actions in the area of ecosystem services for farmers and public administration staff on all levels

pg. 12 - 14

- improving the cooperation among various government departments (MoE, MoA, Ministry of Regional Development), Ministry Agencies, and public administration offices on a local level regarding the preparation of legislative as well as non-legislative measures. Although ecosystem services as a cross-cutting issue fall within the competencies of all of the mentioned government departments, cooperation, such as could be procured by means of interdepartmental working groups, is not sufficient at present. pg. 12 - 14

- interconnection of the issues of ecosystem services and their assessment with the current agenda of various government departments: e. g. with the preparation of the already approved Strategy of the Ministry of Agriculture 2016-2030, the forthcoming National Action Plan for the Strategy on Adaptation to Climate Change in the Czech Republic, or with the forthcoming document Czech Republic 2030 (follow-up document to the currently valid Strategic Framework for Sustainable Development in the Czech Republic), etc. pg. 12 - 14

- triggering and streamlining the procedures for proposals and implementation of pg. 12 - 14

land consolidations as a tool for agricultural land and landscape management

- pg. 12 - 14 addressing the ownership/tenancy land rights. These determine e. g. the farmers' willingness to take part in measures for water regime improvement and water resources protection (spinneys, ditches, furrows, paths but also wetlands).
- pg. 12 - 14 motivating farmers to reduce large land block areas, especially those planted with monoculture crops, as part not only of land consolidation but also as farming management practice (GAEC criteria)
- pg. 12 - 14 preparation of subsidy titles for protective agricultural management as a public service, with a view of preserving the preset conditions for at least 15 years
- pg. 12 - 14 raising farmers' awareness of ecosystem services other than supplying ecosystem services
- pg. 12 - 14 preparation of training programmes adjusted for farmers relating to legislation and connected with the training of state administration staff and students (separate as well as common workshops)

Modelling of ecosystem services

- pg. 16 - 20 based on the modelling of the rainfall-runoff and soil erosion processes it is recommended to develop a more strict definition regarding land use and management within erosion-endagered areas, as in the overwhelming majority of erosion events (detected or modelled within the LaPlaNt project), the GAEC standard is not found to have been violated
- pg. 18 – 20 protective crop rotation together with technical measures was evaluated as the best approach for diminishing soil erosion to an acceptable level.
- the biggest water erosion still arise from long uninterrupted slopes leading directly to a stream pg. 18-20
- conversion of arable land to grassland for improvement of water quality should target the proper areas, the so-called source areas. pg. 18 - 20
- a precise delimitation of source areas on arable land and conversion to grassland represents an efficient and relatively inexpensive measure of enhancing the quality of shallow ground waters or the local drinking water sources pg. 21 - 23
- cattle slurry application rate of up to 120 kg N ha^{-1} with 2 to 3 annual cuts are recommended for grassland areas pg. 24 - 25
- grasslands are important for carbon storage and their occurrence in the landscape represents an important contribution to the regulating ecosystem service pg. 24 - 25
- organic fertilisation of meadows (e. g. with cattle slurry) significantly enhances soil carbon sequestration pg. 24 - 25
- environmentally respectful agricultural and forest management can increase the evapotranspiration rate on average by 40% pg. 26 -27

Policy level of ecosystem services

- implementation of mitigation measures as well as the whole land consolidation process should be presented as an important public interest in order to enhance general acceptance of different stakeholder participation pg. 28 - 30

it is recommended to set up the relevant subsidy system as a stable and long-term public interest support in the form of public service based on precisely defined land management conditions pg. 28 - 30

Stakeholder engagement (Technical Brief 1)

Evaluating and taking into consideration the attitudes of relevant stakeholders towards farmland management from the perspective of sustainable agriculture, water resources and environment protection plays an essential role in harmonising and assessing the feasibility of different claims and goals of these stakeholders as well as of different agricultural land use options (Prager et al. 2009, Hojberg et al. 2013, Ravier et al. 2015). In the LaPlaNt project, three respondent groups closely linked to the agricultural land and landscape management were chosen as representatives of these stakeholders. The groups consisted of farmers, public administration officers and students, respectively. Questionnaires were made to evaluate the attitudes of different stakeholder groups towards the relations between agriculture and ecosystem services. The questionnaires consisted of 20–28 questions or statements ranging from general to rather technical topics using the 1 (definitely yes) to 5 (definitely not) answer scale. The questionnaires further contained some characteristics of the respective respondent group. Farmers, for instance, reported the average size of land block, total area of farmland, average slope of farmland, and proportion of rented and owned farmland. The officers were asked to give their age, gender, and professional specialisation (employer); students, in turn, age, gender, size of town of residence (village/town), and type of school. The evaluation of the results was carried out by analysing the frequency of answers according to the surveyed characteristics and the attitudes to the questions using the Generalized Linear Models (GLM) that enable evaluating the effects of various independent variables as well as expressing the proportion of the variability by the variable itself including interactions.

The aim of the questionnaire survey was to obtain information on how particular stakeholders perceive and assess the current agricultural land uses including socio-economic aspects in the context of water resources, soil and environment protection, and to compare the attitudes of the stakeholder groups.

A brief evaluation of the attitudes of three aforementioned respondent groups to the relations between agricultural and environmental issues is given below. The results include feedback from these three groups from a workshop held in May 2016. This workshop enabled the representatives of all the three groups to react to the attitudes of the remaining groups, which means that feedback was provided not only to the authors of the survey but also to the stakeholders themselves. This provided mutual awareness of the opinions of the other groups as well as important interactions and understanding.

Students’ perceptions of ecosystem services (ES)

Positive perceptions of the ES

The study based on a survey of 967 students from 4 schools in Highland (Vysočina) region, CR showed that students’ attitudes towards the environmental issues were more positive in comparison with other groups regardless of students' gender, age, educational level, place of residence and specialization. The study also showed a strong significant difference (both at $p<0.05$ and $p<0.01$) between male and female students towards perception of ES in general and in particular to questions related to basic environmental education and their attitudes and engagement in voluntary environmental activities.

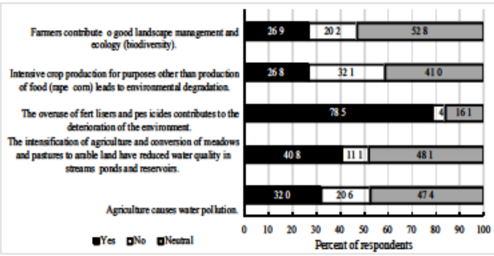

Fig. 1: Students’ perceptions of environmental impacts derived from agricultural activities (N=965)

Gender differences in perceptions of ES

Gender appeared to be the most influential factor among the other factors (age, place of residence, education level and specialization) in determining students’ environmental perceptions particularly those related to basic environmental education. In this regard, female students responded more positively than males.

Female students in general engaged themselves more in environmental activities than their counterparts.

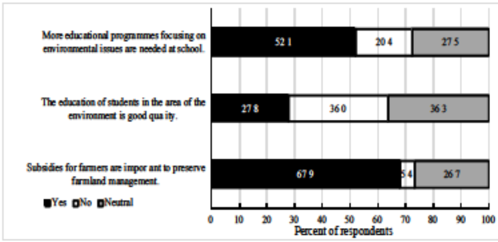

Fig. 2: Students’ perceptions of subsidies and environmental education program (N = 965)

The results of our study indicated that, in general, the students (in all four schools) perceived the effect of agricultural activities on the environment and the need for implementing measures to reduce the negative impacts of agriculture on ecosystem services. For instance, all students irrespective of gen-

Fact box - students and environmental perceptions

One of the commonly studied population groups in environmental studies are students of different gender, age, education level and how these variables impact their perceptions of Ecosystem Services (ES). Understanding students’ perceptions on environmental issues is fundamental for the design of policies to enhance their environmental awareness and sensitivity, to support development and use of sustainable practices, methods and products. Environmental perceptions are affected by host of factors including socio-demographic characteristics that change in space and time. The results of the performed survey show the students' awareness of the relations between agriculture and the environment generally as good. On the other hand, a need for strengthening environmental education was revealed, especially at the policy-making level.

der recognised that intensive farming is one of the major causes for environmental degradation and hence there is an urgent need for nature protection and biodiversity enhancement. The students suggested that there is a need for more environmental courses to be offered in the schools in addition to outdoor activities that raise environmental awareness. Future research should include more detailed environmental surveys targeting schools and other institutions.

Students today are managers and custodians of future environment. How they perceive the environment matters for a country. Differences and commonalities exist among students based on gender, age, place of residence, education level and specialization on environmental perceptions and factors influencing their decision-making.

The findings of this study will provide baseline information for further environmental studies targeting school students in other regions in CR. The results also provide insights into the current emphasis on environmental education at schools and the need for improvement through policy support.

Results of the workshop in Jihlava

The findings described above were mostly confirmed during group work discussions with participating teachers on a project workshop in Jihlava.

The most important insights based on teachers' daily practice are as follows:

- Girls are more social, empathetic, communicative, willing to cooperate, the issue is closer to them;
- For boys, it is logical to consider land predominantly for food production;
- For both genders the quality of food is important for other reasons - origin of food for boys and its nutritional value (healthy eating) for girls;
- Younger students are more submissive and tend to convey the views of parents and teachers whereas more crystallized opinions and criticality are typical for older students;
- Environmental issues are closer to the students from smaller communities than for those from towns, however, this difference is gradually disappearing due to the development of education and widespread availability of information;
- Students of general specialization dispose with a more comprehensive range of information and educational foundation, they are more motivated to education and may pose even a greater mental capacity; vii) Students from the agricultural school may be more oriented to farming production and their perception of environmental aspects related to agricultural land management can be suppressed.

More information in: Tesfai, M., Nagothu, U. S., Šimek, J., Fučík, P. 2016. Perceptions of Secondary School Students' Towards Environmental Services: A Case Study from Czechia. International Journal of Environmental and Science Education, 11(12):5533-5553. http://www.ijese.net/.

Farmers

97 representatives of agricultural companies were addressed in the Highland (Vysočina, 68%), Central Bohemian (15%), Pardubice (12%) and South Moravian (5%) Regions. These respondents were selected in such a way as to represent a typical sample of agricultural companies as regards the farmland area, average land block size, proportion of owned and rented land, natural and agricultural conditions (e. g. production area). The questionnaires contained 28 questions or statements concerning the relations between

the environment and agriculture ranging from general to rather technical topics. In total, 34 completed questionnaires were submitted by the respondents. The original five categories (definitely not – rather no – neutral – rather yes – definitely yes) were transformed into three (no – neutral – yes) due to the low number both of submitted questionnaires and the responses to some questions/categories. The majority of the respondents (53%) farmed areas > 1 500 ha; 33% areas of 500 – 1 000 ha. 47% of the respondents farmed land blocks of average areas of up to 10 ha; 41% of up to 20 ha, 12% more than 20 ha. 38% of the respondents had a proportion of less than 15% of their own land, 35% farmed 15 – 25% of their own land and 27% of the respondents farmed more than 25% of their own land.

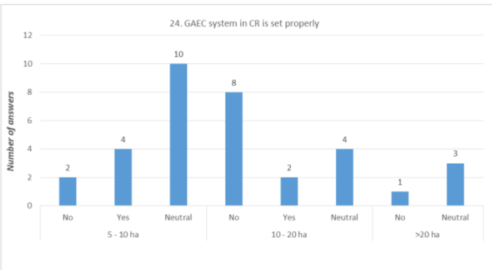

Fig. 3: Farmers' responses to the GAEC issues were related to the average land block area

Evaluation

In the general statements there was a relatively pro-environmental agreement among the farmers: 97 % of the respondents considered the environment protection important, 74 % considered water pollution to be a very important issue, 26 % an important issue, and 91 % of the respondents thought good environmental conditions to be of public interest. The attitude towards the current state of agricultural land in the CR was as expected: 53 % considered it to be satisfactory, 35 % was neutral and 12 % of the farmers believed it was not satisfactory.

The responses to the more specific questions or statements indicate possible interrelation with the abovementioned characteristics of the agricultural companies. Around 30 % of the farmers agreed that *the intensification of agriculture and ploughing up of grassland had reduced water quality in streams, ponds and reservoirs*, 41 % was neutral and 29 % disagreed. About 35 % of the farmers agreed with the statement that *the overuse of fertilisers and pesticides contributes to the deterioration of the environment*, 41 % had a neutral opinion and 24 % disagreed. The

Fact box - farmers

Experience from other countries shows the usefulness of involving the attitudes and knowledge of farmers into river basin and landscape management. This was also confirmed by the information obtained both from the questionnaires and the Laplant final workshop. It was found that the farmers' awareness of the effects of agriculture on the environment decreased with increasing land block sizes. Large land bocks with monoculture crops also play an essential role in water erosion. Land rights and ownership are key factors for the farmers' willingness to adopt protective measures on agricultural land – a big proportion of rented land tends to aggravate these activities. Subsidies related to adoption and management of protective measures on farmland should also act as a public service support .

answers of the respondents showed a significant statistical difference ($p<0.05$) related to the average land block (LB) size. Respondents with smaller LB size expressed more positive and neutral attitude. On the other hand, those with a LB of 10–20 or more ha gave rather negative/disagreeing responses. The results were similar with responses to the question *whether the GAEC system has been set in an appropriate way*. Again the farmers farming on smaller land blocks expressed agreement or neutrality whereas farmers with larger average land block areas showed disagreeing attitudes.

Approx. ¾ of the respondents agreed with the statement that the maintenance, restoration or partial elimination of drainage systems help improve the water regime in the landscape and the quality of water.

Fig. 4: Farmers readily present their opinions if they are listened to

Results of the workshop in Jihlava

The farmers participating in Jihlava workshop were confronted with the questionnaire survey results. The reactions of the farmers to the agricultural subsidy policy and regulations were especially inspiring. Approximately half of the respondents believed that the current subsidy system for farmers had been set in an inappropriate way and another third of the respondents expressed a neutral attitude to the subsidy policy.

The farmers stated that the subsidy system should focus more on retention of water in the landscape as a public interest in the form of public service. Approximately half of the respondents considered the EU directives (Nitrates Directive, Water Framework Directive) to represent a serious limitation for farming efficiency. According to the farmers, these regulations often do not respect natural cycles. However, farmers are strictly bound to calendar terms (farmers would for instance suggest the application of manure even in the currently banned period provided there are good weather conditions). Farmers further suggested that areas vulnerable to nitrate pollution should be delimited by the boundaries of hydrological units (e. g. 4th grade catchments or even smaller units – subcatchments), not as administrative units (cadastral zoning), Mareček, et al. (2016). These suggestions correspond with a number of findings both in the CR (Fučík et al. 2015) and abroad (Ravier et al. 2015, Jordan et al. 2012). Nearly one half of the respondents (41 %) expressed negative (9 %) or neutral (32 %) attitudes towards wetlands on agricultural land as a feature enhancing water quality and biodiversity. Farmers commented the fact stating that they do not object to wetlands from the management perspective and agree with their location wherever it makes sense. However, they do perceive some hindrances in the land right system (discrepancies between the interests of land owners and tenant farmers). In addition, farmers commented on the document Strategy of the Ministry of Agriculture 2016-2030. The farmers know the document but say it presents a strategy that proposes and demands, however lacks the specification of procedures and tools to achieve the ambitious goals. Especially missing are the financial aspects and possibilities regarding the required changes in farmland management (Mareček et al. 2016).

More information in: Fučík, P. et al. 2016. Zemědělské hospodaření a ochrana životního prostředí – jak to vidí zemědělci. Vodní Hospodářství, 9:1-5 (in Czech).

Governmental agencies

The questionnaires were distributed via email among 367 respondents from April to December 2015. The respondents had been selected based on previously analysed groups, which consisted of several hierarchical levels:

- staff of the Ministry of the Environment (MoE)
- staff of the Ministry Agencies of the MoE
- staff of the river basin management state enterprises
- staff of the Protected Landscape Areas (PLA)
- staff of the state enterprise Lesy ČR (*Forestry CR*, LCR) and Waterstream management department of LCR
- staff of the state administration Regional Authorities (RA)
- staff of the Municipalities with Extended Competence (*ORP*, MEC)

All respondents were addressed based on their work tasks, which means that they were dealing with environmental issues, sustainable development, agriculture, and ecosystem services of all categories.

Evaluation

The evaluation of the questionnaire survey was based on a total of 102 submitted responses.

The evaluation of the statistical inquiry showed neither gender nor age of the respondents working in state administration were of significant statistical importance concerning the given answers. This seems to be a consequence of relevant education and work experience of the participants. At the same time, the effect of work position (rank within the public administration system) was also found statistically unimportant.

Approximately 13.8 % of the respondents stated that their work tasks were not connected to ecosystem services and 25.5 % gave a neutral response, which amounts to 39.4 % of the respondents who do not, or think they do not, have a professional relation to ecosystem services.

For two thirds of the respondents, the current state of the landscape is not satisfactory (78.4 % in total, 47.1 % rather no, 31.4 % definitely not). In addition, the respondents (71.6 %) claim that the main purpose of landscape should be the production of food. Vast majority of the respondents (99 %) consider important to preserve nature and landscape for future generations.

Tab. 1: Proportion of the officer's neutral responses to questions relating to legislation

Question	Neutral answers (%)
Implementation of GAEC measures into practice improves management on agricultural land; the GAEC is set properly in CR	63.7
EU Directives (Nitrate directive, Water Framework Directive) introduce serious restrictions for farming	52.0
The inspection process of farming procedures done by the state is sufficient	51.0
My suggestions on legislative as well as non-legislative measures for environmental protection are accepted by the management	47.1

Statistically important positive responses (82.4 % and 67.6 %) were given both to the questions closely related to establishing important landscape features (wetlands, grass strips, bodies of water, etc.) and to those focusing on suitable crop rotation and catch cropping (99.0 % and 88.2 %, respectively).

An important result of the survey evaluation is the majority of neutral responses to the questions related to the existing and emerging legislation and policy-making materials (47.1 % to 63.7 %), and to the education of farmers (64.7 %); see Tab. 1

Results of the workshop in Jihlava

Competences dispersed among various ministries, in particular the MoE and Ministry of Agriculture (MoA), pose a general and long-standing problem regarding the implementation of specific legislative and non-legislative measures aiming to enhance the soil and landscape conditions and biodiversity. Guidance in the field of environment protection is running; however, it is not fully functional for the agricultural sector. This also results in deficiencies concerning the setting of the GAEC standards including the inspection of their implementation. In the long run, according to the information obtained from the officers, it is therefore necessary to establish effective mutual communication among different government departments and public administration bodies on a local level (RA, MEC, municipalities).

However, the confrontation of the farmers' and public servants' experience revealed that there was hardly an agreement between the two groups. Farmers believe that the officers lack practical experience to propose relevant measures. This opinion was also supported by the youth workers.

Fig. 5: Public officers discussing survey evaluation results

The issue of a joint education for farmers and public administration officers was also discussed. Although there are various education programmes for either respondent group, a joint educational platform facilitating mutual understanding to address the common issues is still missing in the CR. This also results in the officers' lack of practical knowledge on farming management, the consequence of

Fact box – governmental agencies

The questionnaire survey as well as the final workshop revealed that the public administration officers dealing with agriculture and environmental issues need more practical experience. Although the officers' awareness of the environment is rather satisfactory, they lack information on recent development in the area of different types of ecosystem services and functions at landscape level, especially those connected to agriculture. Public administration efficiency in dealing with agricultural land management can be also enhanced by active communication with farming companies. Such communication should take place on all levels – starting from local administration offices with special focus on relevant ministries and ministry agencies.

which is a rather repressive approach in dealing with the detected deficiencies.

The neutrality of the officers' responses concerning legislative and policy-making materials was, as the workshop revealed, a consequence of the fact that these materials are not handled on the lowest levels of public administration and they are thoroughly studied only from the regional level up.

The results of the inquiry show that nearly three quarters of the public administration respondents think that the state of agricultural land is not satisfactory. In discussing the main causes of this fact, officers emphasised large land blocks, inappropriate crop rotations, growing energy crops, using heavy agricultural machinery bringing about soil compaction, building up of agricultural land (including photovoltaic power plants), excessive use of fertilisers including massive use of pesticides endangering biodiversity and food quality, lack of organic fertilisers as well as the fact that tenant farming does not motivate to preserve good soil conditions. However, as the farmers' representatives pointed out, this list cannot be broad brushed. Nevertheless, an agreement was achieved as to the ways of improving agricultural land, such as technical measures, "mosaic-pattern" meadow cut, acquiring smaller machinery to achieve reduction in land block sizes and soil compaction, establishing furrows, spinneys and wetlands.

Summary

The questionnaire survey and Jihlava workshop brought stimulating information from three respondent groups dealing with agricultural land management and planning and/or environment protection. The Jihlava workshop enabled representatives of all the three groups to comment on the attitudes of the others, which was regarded as positive by all participants and a highly effective means of mutual communication.

The questionnaire responses revealed that farmers, officers as well as students had similar, i. e. agreeing attitudes regarding the basic general issues such as the importance of environment protection, water quality, and good state of the environment as a public interest. Farmers thought the condition of agricultural land in CR to be rather satisfactory, unlike nearly 80 % of the officers who believed the opposite.

Positive attitudes towards the role of wetlands, balks, spinneys or grass buffer zones for enhancing water retention and quality and soil erosion control at landscape level were also found across the respondent groups.

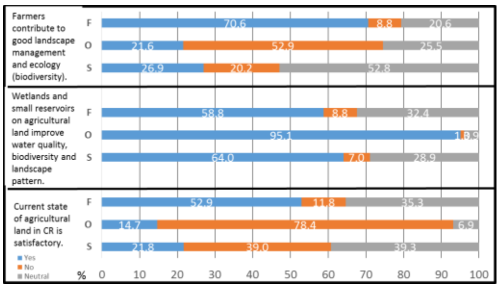

Fig. 6: Comparison of the attitudes of three respondent groups; F – farmers, O – officers, S - students

According to the farmers, however, it is necessary to tackle the ownership/tenancy issues on relevant land plots as well to set up an appropriate subsidy system. Growing crops for purposes other than food production was considered environmentally questionable especially by the officers but also by some farmers. Similar attitudes were expressed by the farmers (yes 67 %) and officers (yes 65 %) towards the restoration or, in well-founded cases, elimination of drainage systems for the enhancement of water regime and water quality in the landscape.

Farmers believe that the state administration lack practical experience to propose relevant measures for soil and water protection including inspection. This opinion was also supported by the youth workers.

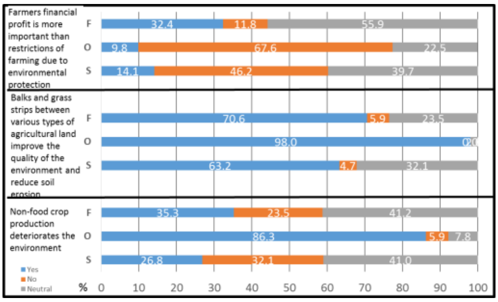

Fig. 7: Comparison of the attitudes of three respondent groups – three other questions

Recommendations

Based on the findings mentioned above it is recommended to encourage:

- workshops and other training actions in the area of ecosystem services for farmers and public administration staff on all levels
- workshops and other training actions enabling better interconnection between the activities of public administration and farming companies and enhancing the possibilities of mutual communication in order for the officers to get acquainted with farm work (not only on inspection visits) and with practical problems and solutions to enhance decision-making
- Improving the cooperation among various government departments (MoE, MoA, Ministry of Regional Development), Ministry Agencies, and public administration offices on a local level regarding the preparation of legislative as well as non-legislative measures. Although ecosystem services as a cross-cutting issue fall within the competencies of all of the mentioned government departments, cooperation, such as could be procured by means of interdepartmental working groups, is not sufficient at present.
- Interconnection of the issues of ecosystem services and their assessment with the current agenda of various government departments: e. g. with the preparation of the already approved Strategy of the Ministry of Agriculture 2016-2030, the forthcoming National Action Plan for the Strategy on Adaptation to Climate Change in the Czech Republic, or with the forthcoming document Czech Republic 2030 (follow-up document to the currently valid Strategic Framework for Sustainable Development in the Czech Republic), etc.
- Triggering and streamlining the procedures for proposals and implementation of land consolidations as a tool for agricultural land and landscape management optimisation including the protection of urban areas
- Addressing the ownership/tenancy land rights. These determine e. g. the farmers' willingness to take part in measures for water regime improvement and water resources protection (spinneys, ditches, furrows, paths but also wetlands).
- Motivating farmers to reduce large land block areas, especially those planted with monoculture crops, as part not only of land consolidation but also as farming management practice (GAEC criteria)
- Preparation of subsidy titles for protective agricultural management as a public

Fig. 8: NIBIO partners discussing the methods of farmland management optimisation with active involvement of farmers in Jihlava

service, with a view of preserving the pre-set conditions for at least 15 years

- Raising farmers' awareness of ecosystem services other than supplying ecosystem services
- Preparation of training programmes adjusted for farmers relating to legislation and connected with the training of state administration staff and students (separate as well as common workshops)

Farmers, public administration workers as well as students and youth workers are important and indispensable stakeholders in the process of landscape management optimisation from the perspective of a sustainable way of life. Such optimisation inevitably involves a compromise solution for an economically effective agriculture as well as soil, water quantity and quality protection and biodiversity enhancement.

The possibilities and means for achieving their particular goals are different for each group. However, without mutual respect and support these goals cannot be achieved in the required quality and at the same time no group will be really satisfied. It is therefore obvious that the measures to protect soil and water and enhance biodiversity as well as other non-productive functions on agricultural land will not work unless farmers accept these measures as well-founded and both farmers and public administration officers identify themselves to at least some degree with their necessity. It is the farmers, in the end, who are to a great extent the real landscape managers, as may be leart from the centuries-old history of Central Europe and Norway.

More information in: Fučík, P. et al. 2016. Zemědělské hospodaření a možnosti ochrany prostředí očima úředníků, zemědělců a studentů – zkušenosti z projektu LaPlaNt. Vesmír, 95:600–601. (in Czech).

Modelling of ecosystem services (Technical Brief 2)

In the LaPlant project, five different areas linked with ecosystem services were quantified – flood control (Rainfall-Runoff), erosion regulation (Soil Erosion), water purification (Water Quality) and Plant Biodiversity. The fifth one was the monetary evaluation of Ecosystem Services. For instance, the conversion of arable land into grassland stands as one of the protective measures to enhance surface and subsurface water quality. In addition to the increased capacity to absorb and utilise more soil nitrogen as compared to field crops, the regulating ecosystem service of permanent grassland (PG) lies in the enhancement of microclimate and soil water retention occurring for a longer period during the year. Thus, various options of agricultural land management profoundly influence the landscape ability to retain water, intensity of soil erosion, water quality and also plant diversity. Several (5-7) scenarios were modelled in three agriculturally exploited pilot sites in the Czech Republic to manifest how different land management manners may influence aforementioned ecosystem services.

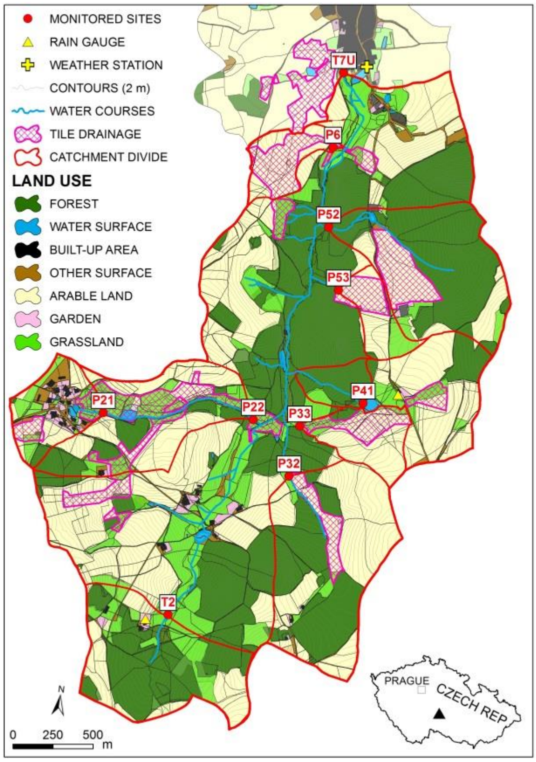

Fig. 9: Kopaninský stream catchment

The sites were:

i) The Kopaninský stream catchment with an area of 710 ha (Fig. 9). Here, modelling of rainfall-runoff and soil erosion processes took place.

ii) Dehtáře - 60 hectares tile drained catchment, used for modelling of water quality. Moreover, water quality has been modelled also in other larger catchments within Vltava River Basin.

iii) Vadčice pilot site – demonstration of how different cattle slurry application rates influenced hay yields and plant biodiversity of three cut grasslands.

Modelled scenarios were also used to show the efficiency of mitigation measures or consequences when keeping the rules given by the actual policy in CR (DZES / GAEC).

Tab. 2: Evaluated scenarios of land use and management as modelled in LaPlaNt

topic	Scenarios for modelling and evaluation in LaPlaNt						
	1	2	3	4	5	6	7
Rainfall - runoff process	Current state	Maize on whole catchment ploughland	Soil-protective crop rotation with the use of agro-technical measures on all land block with ploughland	Forest on all land blocks with ploughland	Grassland on all land blocks with ploughland	A technical measure - a ditch interrupting a long slope	
Soil Erosion	Current state	Maize on whole catchment ploughland	Soil-protective crop rotation with the use of agro-technical measures on all land block with ploughland	Forest on all land blocks with ploughland	Grassland on all land blocks with ploughland	A technical measure - a ditch interrupting a long slope	
Water Quality	Current state	Increae of ploughland by 20% in the catchment	Increase of grassland by 10% in the catchment	Increase of grassland by 20% in a catchment	Increase of grassland in tile-drainage subcatchments by 10%		
Plant Biodiversity	Grassland uncut	Grassland mulched 3x year	Grassland cut three times per year with various doses of cattle slurry applied				
			S0=0 kg $N.ha^{-1}.y^{-1}$	S1=60 kg $N.ha^{-1}.y^{-1}$	S1=120kg $N.ha^{-1}.y^{-1}$	S1=180 kg $N.ha^{-1}.y^{-1}$	S1=240 kg $N.ha^{-1}.y^{-1}$

Rainfall – Runoff processes

The HEC – HMS model was used to model six scenarios of land use and management on rainfall-runoff in Kopaninský stream catchment. The model was calibrated using measured runoff data from monitored sites within the catchment. The model was calibrated for

Tab. 3: Protective crop rotation

year	crop	description of measures (cropping, tillage)
1	red clover	-
2	winter wheat	after clover; sowing in ploughed land
3	corn for silage	after grain, pulses, oilseeds; sowing in mulch, stubble, ploughless
4	spring barley	after root crops; sowing in mulch, stubble, ploughless
5	winter rape	after grain, pulses, oilseeds; sowing in ploughed land
6	winter wheat	after grain, pulses, oilseeds sowing in mulch, stubble, ploughless
7	potatoes	-
8	spring barley	undersown with clover

watershed soil, plant, tillage and vegetation conditions during a rainfall-runoff (R-R) event, which took place on 22.6.2011. This was a short and intense rain storm with a single runoff peak, which is the type of a rain storm the model is able to simulate most accurately. The course of the R-R event, the real runoff catchment response observed in the watershed outlet T7U as well as modelled scenarios are illustrated in Fig. 10. For the simulations, seven scenarios were proposed and assessed.

Agricultural land management scenarios were in detail:

1) Real crop rotation in the period 2008 – 2014 (w. barley, rape, w. wheat, maize, maize, s. barley, rape)

   Hydrologic characteristics were calculated based on the real crop rotation for each land block.

2) Erosive dangerous crop – maize on all land blocks with arable land

3) Protective crop rotation with the use of agro-technical measures on all land blocks with arable land (see Tab. 3)

4) Forest on all land blocks with arable land

5) Grassland on all land blocks with arable land

6) Grassing 1 – Increase of grassland by 10% of the catchment area (i.e. by 70 hectares); grassland is put on arable land - infiltration vulnerable areas

7) Grassing 2 – Increase of grassland by 20% of the catchment area (i.e. by 140 hec-

tares) - grassland is put on arable land - infiltration vulnerable areas and erosion prone areas

Influence of vegetation (crop / plant) cover in the HEC – HMS model is given by the CN parameter. For all scenarios, new CN were derived according to the change in vegetation cover and applied in the model. Response of the watershed to the rainfall event for different farm management is illustrated in Fig. 10.

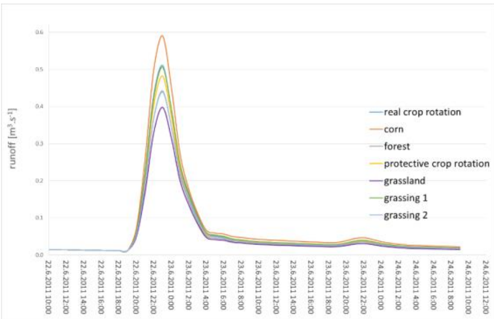

Fig. 10: Runoff response of catchment outlet with different land use and management scenarios

Furthermore, simulations of runoff response to rainfall event in detail on P32 subwatershed have been performed. The area of the subwatershed is 0.71 km^2. It has relatively steep and long slopes of agricultural land blocks without interruption of surface runoff - in its north eastern part. In the southwestern part of the subwatershed, there are forests and smaller agriculture land blocks with some runoff-interrupting lines between their boundaries.

The average slope is 7.5 % and the longest slopes without surface runoff interruption are about 450 m long. All the land blocks are arable land. There is a permanent stream flowing in southeast – northwest direction. The subwatershed is illustrated in Fig. 11. Agricultural land management scenarios

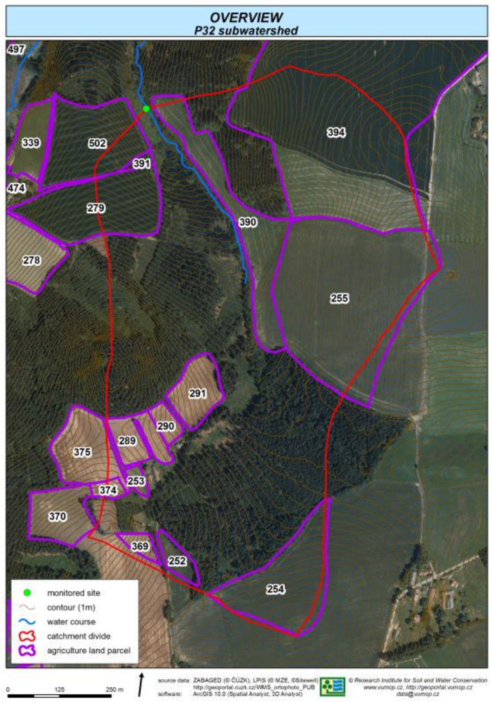

Fig. 11: Overview of P32 subwatershed

Fact box – setting land management to enhance water retention

Decreased ability of agricultural land to retain water is a worldwide problem. By setting the optimal land management, a profound improvement of water retention could be achieved. A change of land use and management towards crop protective rotations, forests and grasslands is recommended. However, these actions should be accompanied by technical measures like ditches and furrows which enable to catch or slow down water runoff in the upper parts of the slopes.

Tab. 4: Runoff response of P32 Subwatershed with different farmland management

	real crop rotation	corn	protective crop rotation	technical measures	forest	grassland
Peak discharge [$m^3.s^{-1}$]	0 009	0 0118	0 0087	0 0075	0 0083	0 0078
Peak discharge [%]	100	131 1	96 7	83 3	92 2	86 7
Volume [1000 m^3]	0 27	0 34	0 26	0 23	0 25	0 24
Volume [%]	100	125 9	96 3	85 2	92 6	88 9
specific discharge [$m^3.s^{-1}.km^{-1}$]	0 0127	0 0166	0 0123	0 0106	0 0117	0 011
specific discharge [%]	100	131 1	96 7	83 3	92 2	86 7

were the same as for the whole catchment, and one with one technical measure - two infiltration furrows (gutters) and one diverting furrow on No. 255 and No. 390 land blocks were added. This scenario was modelled together with real crop rotation farm management.

Results

Simulations of the real state showed that the current farmland management within the watershed is not satisfactory in terms of adequate protection against surface runoff. The best protective effect on water retention had grassland and forest, with the densest canopy cover all over the year.

According to the expectations, the less suitable crop for such a hilly watershed appeared to be corn. Protective crop rotation and technical control measures were evaluated as good options to improve the situation, but in case of this watershed, applied technical measures were still not sufficient enough. The combination of protective crop rotation and technical measures would probably be a reasonable solution.

Recommendations

For the proper management of agricultural land located in an even mild-hilly area, the adoption of technical measures in order to retain water is indispensable. The modelling results showed the measures are best when accompanied with protective crop rotation and / or placing grassland on the slopes. The large field blocks should be disintegrated into smaller parcels, as the surface runoff occurs even on minor slopes of these vast land blocks.

Soil Erosion

Soil erosion within different farmland management scenarios (see Tab. 2) was assessed in the Kopaninský watershed and in the P32 sub-watershed using the Universal Soil Loss Equation (USLE). Soil erosion for the real crop rotation in period 2008 – 2014 was calculated to illustrate the real, bench-mark-state of the watershed. Further, four different scenarios of vegetation cover were applied to show the influence of different farmland management on soil erosion. On P32 subwatershed, scenarios with technical measures were also applied. Below, the results for P32 sub-watershed are given and discussed.

Results

Simulations of the real state showed, as well as in the rainfall-runoff modelling that the current farmland management within the watershed is not satisfactory in terms of adequate protection against soil erosion. The best protective effect on erosion had grassland and forest, with the most dense canopy cover all over the year. According to the expectations, the less suitable crop for such a hilly watershed appeared to be corn. Protective crop rotation and technical control measures were evaluated as good options to improve the situation, but at the case of this watershed, applied technical measures were still not sufficient enough. The combination of protective crop rotation and technical

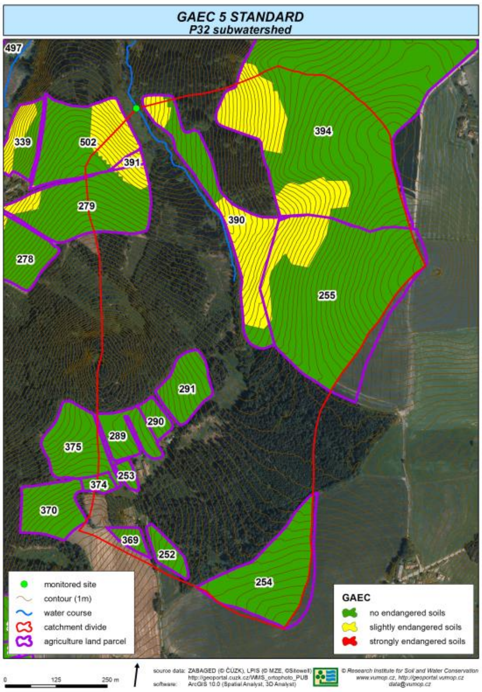

Fig. 12: GAEC 5 categories for erosion endangered fields in P32 subwatershed

measures would be a reasonable solution. Simulation of keeping GAEC 5 standard (Fig. 13) showed that the current setting of the GAEC-based rules does not protect the soil in accordance with the soil loss tolerance and a more strict definition regarding land use and management within erosion-endangered areas in GAEC is needed.

It was revealed that the most problematic area in terms of water erosion is long uninterrupted slopes which lead directly to a stream. From all the modelled scenarios, only management excluding planting crops; i.e. grassland and forest can effectively protect the soil. No other scenarios are efficient enough. To keep GAEC 5 standard (according to Fig. 12) at this slope means to grow corn with contour tillage in the lower part of the slope instead of conventional tillage with an insufficient effect.

In the technical measures scenario, the hillslope was interrupted by two infiltration furrows and one diverting furrow. In this case, the erosion decreased more significantly directly below the measures thanks to the interruption of water outflow and increase again with the growing distance from the furrow. On such a slope, more measures need to be applied to keep erosion within tolerable limit, which restricts the use of land parcel and would not be accepted by the farmer.

In comparison of agrotechnical and technical measures, the protective crop rotation scenario has slightly lower erosion in the land parcel No. 255, where it can decrease energy

Fact box – effective protection against soil erosion

Protective crop rotation together with technical protective measures was evaluated as good options for diminishing soil erosion to an acceptable level. Further, simulation of erosion control based on the GAEC standard showed that the current setting of the GAEC-based rules does not protect the soil in accordance with the soil loss tolerance and a more strict definition regarding land use and management within erosion-endangered areas in GAEC is needed.

of water more effectively than furrows in the field with conventional management. On the other hand, on the lower part of the slope with a high water energy (land parcel 390), more efficient would be to interrupt the surface runoff completely. The "technical" scenario reaches significantly lower erosion here.

Recommendations

The most effective land management on such long slopes appeared to be a combination of both types of measures and to focus on the whole length / area of the slope. The standards, given by GAEC, should be set more strictly to protect the soil against erosion.

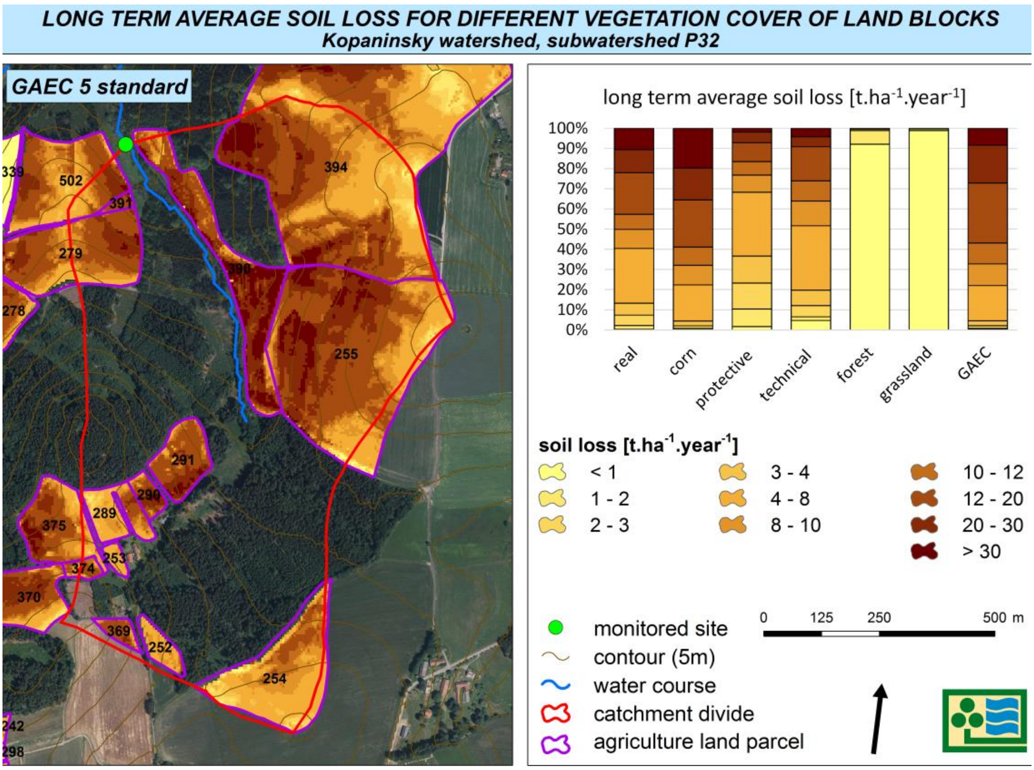

Fig. 13: Long term average soil loss for different vegetation cover of land blocks

Water Quality

Nitrates are one of the most widespread pollutants in waters. The monitoring of nitrate pollution has become a major concern worldwide due to its impacts on human health, surface water eutrophication and economic losses caused by nitrogen leaching from soil. Conversion of arable land to grassland is one of the protective measures to enhance surface and subsurface water quality. This important non-production function of permanent grassland (PG) is associated with its morphological forming (compact swards and dense root system), which allows take up soil nitrogen efficiently and accumulate it in plant biomass (unlike field crops) almost all year round. Soil microorganisms' occurence and activity, which is considerably higher in PG soils

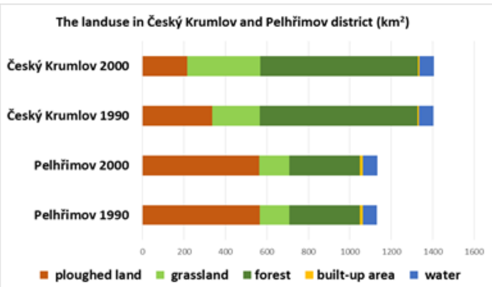

Fig. 14: Land use changes in the districts of Český Krumlov and Pelhřimov in the period 1990 - 2000

compared to arable land, contributes to the retention of nitrates in soil by the immobilization and degradation via denitrification (Griffiths et al., 2008). This enables to apply relatively high nitrogen doses on PG areas without any negative impact on water quality (up to 200 kg / ha / year, Fiala 2002). In addition to the ability to reduce nitrate pollution, PG have is another supporting and regulating ecosystem functions such as carbon sequestration, reduction of soil erosion, improvement of water retention in the landscape and reduction of pesticides leaching (Hönigová et al., 2012).

Land use and water quality

The relations between different land uses and nitrate concentrations in waters are known both abroad and in the Czech Republic. These relations have been tested from small-scale sites or land drainage structures (tens of ha) to large catchments (hundreds of km^2).

To determine the long-term effects of arable land conversion to grassland on water quality (Kvítek et al., 2009), eight catchments in the Český Krumlov district (situated in the upper Vltava basin), in which a significant land use change took place between 1990 and 2000 resulting in an increased proportion of grassed areas (Fig. 14), were compared with 23 catchments belonging to the Švihov reservoir catchment (lower Vltava basin) where no significant land use changes took place. The evaluation showed sharp decline in nitrate concentrations in all of the upper Vltava catchments whereas the changes in the Švihov reservoir area were inconclusive. By analogy, dependence between increasing nitrate concentrations and increasing proportion of arable land in the catchment was demonstrated as well (Fig. 15).

The evaluation of land use and nitrate concentrations carried out in catchments of three different scales (tens of ha, hundreds to thousands of ha, and hundreds to thousands of km^2) in the area of the Bohemian-Moravian Highlands crystalline unit (Fučík et al., 2008) has shown that each reduction in arable land area in the catchment by 10 % may reduce the nitrate concentration value (C90 – 90% quantile) by 6.4 mg/l on average.

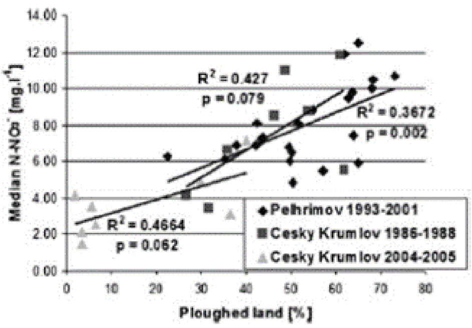

Fig. 15: Dependence between nitrate concentrations and the proportion of arable land within a catchment

Agricultural tile drainage has been found to increase the rate of nitrate leaching from the soil to the water. There are obvious relations between the management of drained land and water quality. Land use of light and shallow soils with low water and nutrient retention seems to have a greater impact on the quality of the drainage water that of heavier soils. This issue was tested on water quality data at 22 drainage systems built in slopy areas underlaid by crystalline bedrocks associated with soil type properties and land use options in their micro-catchments (Fučík et al., 2015). For the proportion of arable land on shallow soils, causal relation in terms of positive correlation was again demonstrated for nitrate concentrations (regardless of water flow). The proportion of grassland on shallow as well as medium-textured soils showed in turn negative correlation, i.e. improved the quality of water.

The analyses described above demonstrated that the proportion of arable land and grassland on the most permeable soils in the micro-catchments of the drainage systems had the greatest effect on nitrate concentrations in waters.

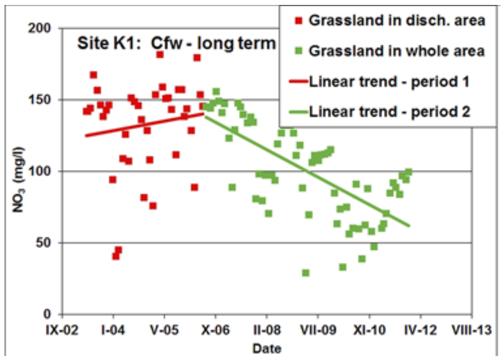

Fig. 16: The change in nitrate concentration trend after conversion of the drainage system source area to grassland

Practical verification of the abovementioned findings on the impact of various uses of different soil types on drainage water quality in various catchment sections was provided by a pilot test in the Dehtáře catchment in 2003 - 2013 (Zajíček a Kvítek, 2003). The experiment itself consisted in conversion of the upper part of this catchment (the so-called source area of 4.6 ha) to grassland and, under continuing common

Fact box – the right zones for targeted grassing in tile-drained catchments

Source areas are parts of slopy catchments where quick infiltration of rainfall into the soil may serve for the recharge of the regional aquifer. Source areas are typically located in the upper parts near the catchment divide where shallow stony soils with low water and nutrient retention and high infiltration capacity occur. It is assumed that source areas are zones where the majority of the discharge water originates, which is further conveyed by land drainage systems built in slopy areas. These zones are the main sources of drainage water pollution, particularly of nitrates and pesticides. For these reasons, the protection of drainage water and shallow ground waters by means of permanent grassland should target precisely into these zones.

agricultural management, in further monitoring of the changes in nitrate concentrations in drainage and ground waters, changes in drainage discharge as well as nitrogen outputs from different catchment sections. Fertilisation at a rate of approx. 100 - 120 kg N/ha was done mainly with urea and liquid manure as a supplementary fertiliser, and from 2012 also with pig slurry digestate.

At the monitoring sites, considerably varying nitrate concentrations ranging from 18 to 253 mg/l were determined. In the subcatchments whose entire source areas were turned into grassland, statistical analysis of the data on the trends of nitrate concentrations measured at the drainage subcatchments with different land uses before and after drainage showed a decline in concentrations by 26 - 32 % (statistically significant) in the period following the conversion. The decline was registered in spite of the fact that the permanent grassland was continued to be fertilised with urea, liquid manure and digestate. Regarding the drainage group as a whole (20 % of the so-called source area turned into grassland), a decline in concentrations by 11 % was observed. However, the decline in concentrations tends to be rather slow, as the median concentrations of NO_3^- range between 90 - 100 mg/l. This is due to the composition of the drainage discharge water and mean residence time of drainage water in catchment. What is more important from this perspective is a steadily decreasing nitrate concentration trend at locations where the source area was turned into grassland (Fig. 16). In addition to the decrease in nitrate concentration, nitrogen loads from the catchment decreased as well: at the lowest monitoring site of the drainage group whose source area was in part turned into grassland, nitrate loads decreased by 23 % (from 3.2 kg/ha/month to 2.6 kg/ha/month). In the drainage group whose entire source area was turned into grassland, nitrate loads decreased by 47 % (from 4.75 kg/ha/month to 3.23 kg/ha/month). As in the same period the drainage group where land use remained unchanged (arable land) showed an increase in nitrate loads by 17 %, the positive effect of grassing targeted in the source area was proved.

Recommendations

The results of experimental conversion of source areas to grassland as well as the statistical evaluation of nitrate concentrations in the waters of drainage systems under various management regimes in areas of different sizes demonstrate that conversion of ploughland to grassland may represent an effective measure to reduce nitrate loads in waters. However, it should target the right area within the catchment, i.e. the so-called source area. Shallow coarse-textured soils in source areas with low water retention are highly suitable for conversion to grassland, which in addition to improving water quality increases the soil water retention capacity, allowing the infiltration of a larger volume of rainfall as compared with arable land, particularly during larger rainfall-runoff events. Thus a correct delineation of an area to be converted to grassland is an efficient and inexpensive tool for enhancing the quality of shallow ground waters or the local drinking water sources for small communities. It is necessary, however, to implement this measure in relatively small and precisely delimited parts of the catchment in order not to excessively limit the production ecosystem service and function of the landscape.

More info in: Zajíček, A. et al. 2016. Vliv cíleného zatravnění orné půdy na jakost drenážních vod a vybrané ekonomické ukazatele. Úroda, 10:55-58. (in Czech).

Plant Biodiversity

Species diversity of a landscape is reduced by disturbations connected to human activities, such as land use, deposition of atmospheric nitrogen, infrastructure, landscape fragmentation, and climate change. On the pilot site of the Kopaninský stream (Bohemian-Moravian Highland), the effects of these driving forces on biodiversity and its natural state, respectively, were analysed under 6 different scenarios (see Tab. 2, pg 16).

Scenarios 2 and 3 did not show any changes compared to the real state, as they were only crop change scenarios under the same land use pattern not affecting the landscape structure. Scenario 4 showed slight differences due to a transition of one land use type into another. Scenario 5 (conversion of arable land to grassland) showed the most significant positive changes from the perspective of biodiversity preservation. Scenario 6 predicted for 2050 focused on the landscape development trend by projecting future changes and documented the expected negative impact on the existing biodiversity due to climate change.

Within the pilot site of the Kopaninský stream, the most valuable biotopes were identified (herb-rich and acidophilous beech woods, wet thistle meadows and meadowsweet grasslands) representing highly valuable landscape segments where active nature conservation management should be applied to preserve the current state. The second group consists of valuable biotopes representing landscape segments of local biodiversity importance, which nevertheless do not represent important segments on a regional or national level. Here an environmentally respectful management regime should be applied aiming to preserve these biotopes while not excluding economic exploitation. The rest of the area is composed of biotopes of low biodiversity importance where economic perspective may prevail.

At another pilot site, Vadčice in the Bohemian-Moravian Highland, a 7-year research study on the effects of cattle slurry application on the biodiversity of vascular plants in different types of *Arrhenatherum* meadows was carried out. The meadows differed in soil and moisture conditions. One of the experimental sites was located on top of a slope on shallow, stony and permeable soil with occasional soil moisture deficiency. The other site was in turn located on deep soil of medium permeability at the foot of a hillslope. The meadows were cut three times annually and fertilised with different doses of cattle slurry corresponding to 60, 120, 180 and 240 kg of nitrogen (N) per hectare.

One plot was not treated with any fertiliser at all. The cattle slurry was applied at the beginning of the growing season, after the second, and in some cases, the third cut as well. The development of the graminoid species on the permeable soil was limited by lack of water in the soil. As a result, grasses – growing fast if moisture is ample – were suppressed in their development. In consequence, other species – forbs and legumes – were allowed to spread. The species richness was surprisingly not reduced by high doses of cattle slurry (Fig. 17).

The situation was different with the moist meadow where forbs and legumes were suppressed by grasses due to the application of high doses of cattle slurry, and several species also by the three-cut management regime.

Dry herbage yields of both types of meadows differed depending on different slurry doses, i.e. the unfertilised plot had the lowest yield (S0) while the highest yield was obtained using the application pattern of 240 kg N ha^{-1} (S4, Tab. 5).

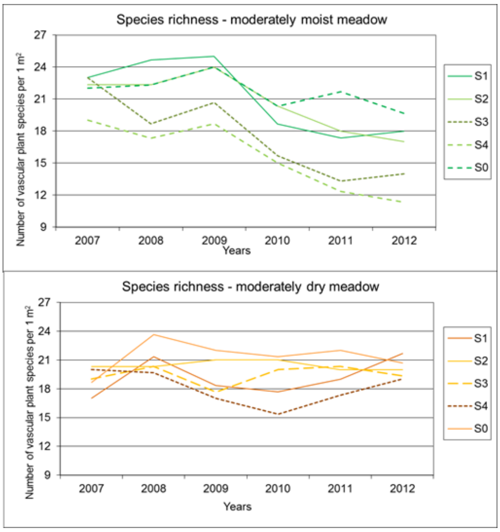

Fig. 17: Species richness of a moderately moist and moderately dry Arrhenatherum meadow, respectively, with different cattle slurry application rates, S0 – three-cut unfertilised; S1 –an application rate of 60 kg N.ha^{-1} of cattle slurry; S2 - 120 kg N.ha^{-1}; S3 - 180 kg N.ha^{-1}; S4 - 240 kg N.ha^{-1}

The table demonstrates that by applying higher doses of slurry (180 and 240 kg N ha^{-1}), high dry herbage yields (> 4 t ha^{-1}) may be obtained even from a moderately dry *Arrhenatherum* meadow under periodic water stress while at the same time preserving the plant species richness.

Tab. 5: Dry herbage yields (t ha^{-1}) after applying different doses of slurry on a moderately moist and moderately dry meadow, respectively.

Herbage dry matter yield t ha^{-1}	moderately moist meadow	moderately dry meadow
S0	5.7	2.2
S1	6.6	3.0
S2	7.4	3.7
S3	8.4	4.9
S4	8.9	5.2
Mean values	7.4	3.8

Recommendations

For both types of grassland, cattle slurry application rate of up to 120 kg N ha^{-1} with 2 to 3 annual cuts can be recommended as a suitable management regime to preserve the plant species richness and at the same time to obtain satisfactory dry herbage yields.

Carbon sequestration in grasslands

As part of the activities carried out on the pilot site of Vadčice, carbon (C) sequestration (storage, uptake) rate in the underground and aboveground biomass as well as in the soil of moderately dry and moderately moist *Arrhenatherum* meadows was evaluated. Carbon is stored in the organic matter of the biomass or soil resulting in a reduction of the amount of carbon dioxide in the atmosphere and mitigation of the global warming process. The

Fact box – plant biodiversity and carbon sequestration supported by human activities

Not only have the most valuable biotopes deserved active nature conservation management. Also biotopes representing segments in agricultural landscape with local biodiversity importance should be properly managed to preserve the required state. Cattle slurry applied on *Arrhenatherion* grasslands at annual rates up to 120 N ha^{-1} seems to be an acceptable compromise between farming requirements (high soil fertility and adequate herbage production) and plant species richness conservation. In addition, considerable soil organic carbon sequestration was found captured as a consequence of cattle slurry application.

Tab. 6: Carbon sequestration in moist and dry Arrhenatherum meadows (t ha^{-1}), Vadčice.

Carbon (C) sequestration of *Arrhenatherum* meadows	moderately moist meadow	moderately dry meadow
aboveground live biomass (t ha^{-1})	2.7	1.4
underground live biomass (t ha^{-1})	4.8	3.7
aboveground dead biomass (t ha^{-1})	0.5	0.3
underground dead biomass (t ha^{-1})	2.4	1.8
aboveground total biomass (t ha^{-1})	3.2	1.6
underground total biomass (t ha^{-1})	7.1	5.5
soil C (t ha^{-1})	76.3	49.7
total C (t ha^{-1})	86.6	56.9
biomass C/soil C (%)	13.6	14.4
aboveground biomass C/underground biomass C (%)	45.0	29.9
aboverground C/underground+soil C (%)	3.8	3.0

content of C in the aboveground dry live biomass was found to be rather stable (36 % on average). In total, for the average of years and different fertiliser application rates, the content was 2.7 t C ha^{-1} in aboveground live biomass for the moister meadow, and 1.4 t C ha^{-1} for the drier one (Tab. 6). The total amount of aboveground biomass (live as well as dead) was 3.2 (moister meadow) and 1.6 t C ha^{-1} (drier meadow). The total underground biomass amounted to 7.1 (moister meadow) and 5.5 t C ha^{-1} (drier meadow).

The evaluation of the amount of soil C was significantly influenced by the depth of the investigated soil. Monitoring of soil organic C at a depth of 3-60 cm (moist meadow with deep soil profile) and 3-20 cm (drier meadow with shallow soil profile) in the period 2007-2013 determined the content of C in the soil profile of the moister meadow to be 76.3 t C ha^{-1}, and in the soil profile of the drier meadow to be 49.7 t C ha^{-1}. As is further shown in Tab. 6, the sequestration of C in aboveground biomass is negligible as compared with the sequestration of C in soil and underground biomass. In addition, the sequestration of C in biomass (aboveground as well as underground) is low as compared with the content of C in soil (approx. 8 x lower). Hence it is the soil organic matter that plays the most important role for the sequestration of C in grasslands.

After 7-year monitoring of changes in the content of soil organic C it was found that after the application of 240 kg N ha^{-1} in cattle slurry, the amount of soil carbon at the moister meadow increased by 12.1 t ha^{-1} as compared with the unfertilised plot and by 10.8 t ha^{-1} in case of the drier meadow.

Recommendations

Grasslands are important for carbon storage and their occurrence in the landscape represents an important contribution to the regulating ecosystem service. Organic fertilisation of meadows (e. g. with cattle slurry) significantly enhances soil carbon sequestration.

Ecosystem services

Ecosystem services (ES) have significant values to human health, well-being and prosperity and are classified into four categories (provisioning, supporting, regulating and cultural services, Power 2010, Frélichová et al. 2014, Grazhdani 2014, Burkhard et al. 2014).

Analysis of climate ES - in general one of the most important regulating ES assessed in the Kopaninský stream catchment is presented in this chapter. This climate ES was analysed based on thermal and hyperspectral aerial photographs reflecting energy fluxes depending on the spatial distribution of different biotopes. The ideal distribution of energy fluxes in a landscape was bound to natural biotopes as woodlands (with fringes of acidophilous lawns on shallow soils), hydrophilous herb communities, and water biotopes (e. g. meadowsweet grasslands, wet ruderal meadows, bushlands) consuming the great part of solar energy for the evaporation from the surfaces of plants, water or soil (so called evapotranspiration rate) and by this way cooling these surfaces. As a result, water was retained in the landscape and, in addition, the differences between the maximum and minimum daily temperatures were reduced.

Due to the time of year (May) at which the aerial photographs were taken, the heterogeneous mixture of crops on arable land showed similar structure of energy balance components as the natural biotopes. Other anthropogenic biotopes including scattered vegetation, hard surfaces and grasslands showed rather great variation and generally lower evapotranspiration rate as a consequence of a varied mosaic-like distribution pattern of small-scale areas and their low water evaporation rates.

Based on the sum of particular current biotope state and area, the value of the climate ecosystem services of Kopaninský stream catchment was determined according to Seják et al. (2010) as a total of € 299 920 069.

Tab. 7 shows to what extent the anthropogenic activities changed (deteriorated) the evapotranspiration capacity of the landscape and the small water cycle in the Kopaninský stream catchment. In comparison with the potential natural vegetation (herb-rich beech woods, acidophilous beech woods), the evapotranspiration rate of the current biotopes in Kopaninský stream catchment was lower by 42 % and the small water cycle was lower by 55 % than that of the natural vegetation.

Tab. 7: A comparison of the evapotranspiration rate and small water cycle between the potential natural vegetation and the current vegetation in the pilot area

Biotope and vegetation type	Evapotranspiration rate (lt yr^{-1})	Small Water cycle (lt yr^{1})
Herb-rich beech	1, 694 000 000	1, 452 000 000
Acidophilous beech	3, 388 000 000	2, 904 000 000
Potential natural vegetation (PNV)	5, 082 000 000	4, 356 000 000
Current vegetation (CV)	2, 945 643 537	1, 938 836 632
CV/PNV (%)	58	45

This means that the water regime of the current vegetation and land use in the pilot area was deteriorated. This had an obvious impact on the surrounding arable land or, in other words, on the water cycle in the surrounding landscape.

Nevertheless, the natural value of biotopes in the pilot area remains relatively high. However, it is advisable that more environmentally respectful agricultural as well as forest management should be implemented instead of intensive land use to prevent irreversible losses of biodiversity and related ecosystem services.

More info in: Cudlín, O. et al. 2016. Hodnocení biotopů zemědělsko-lesní krajiny v souvislosti se změnou klimatu pomocí modelů a GIS nástrojů. Ochrana přírody, 2017, 1. (in Czech).

Fact box – Climate ecosystem services decreased by human activities

Human activities seem to be considerable drivers, which deteriorate water landscape supplies. An example of Kopaninský stream catchment showed that water consumption of the current biotopes for the evapotranspiration rate was lower by 42 % and the small water cycle was lower by 55 % compared to the potential natural vegetation of this area. This had a negative impact on overheating and drying up of the surrounding landscape, increasing the precipitation imbalance and temperature fluctuations.

Policy level of ecosystem services (Policy Brief)

This chapter provides brief description and comparison of the policy and practice regarding environmental and agricultural mitigation measures diminishing for soil erosion, surface water runoff and water pollution in the Czech Republic and Norway, respectively.

Czech policy and practice regarding mitigation measures in agricultural landscape

Agricultural management practices affect the environment in the Czech Republic especially by increasing soil erosion causing sediment and phosphorus inputs into waters. Other agricultural sources of diffuse water pollution include nitrates and pesticides. Good Agricultural and Environmental Conditions (GAEC) standards deal with agricultural practices respecting the protection of the environment, soil and water. They are defined in Government Regulation No. 309/2014 Coll. on determining the consequences of the breach of cross-compliance rules regarding the provision of some agricultural funds. The GAEC standards deal separately with each EU Member State based on the framework laid down in Annex II to Regulation (EC) No. 1306/2013 of the European Parliament and of the Council that contains the following priority issues: water, soil and carbon stock, landscape, minimum level of maintenance of the land. From 2004, the compliance with these regulations or directives is obligatory for farmers in the Czech Republic in relation to various types of agricultural subsidies (direct payments, rural development programme: agri-environmental measures). GAEC measures aiming to reduce damage to the environment include: Establishment of buffer zones along water courses (GAEC 1), Maintaining minimum soil cover (GAEC 4), Limiting erosion (GAEC 5), Maintenance of soil organic components (GAEC 6), and Landscape features, avoiding invasive plant species (GAEC 7).

Erosion control measures are classified into technical, agricultural, and organisational measures. The need for and compliance with them is related to the land block classification into high/medium erosion risk category in connection with the crop type.

Agricultural erosion control measures comprise various soil protection technologies (sowing into mulch, sowing without tillage, post-harvest residues, infiltration strips and other types of strips, contour sowing, etc.). They are used to enhance the soil's infiltration (and retention) capacity, reduce its sensitivity to erosion and protect its surface particularly in the period of the highest incidence of torrential rainfall (June, July, August) when especially high erosion risk crops (maize, potatoes, beet, sunflower, etc.) do not provide sufficient cover due to their size and canopy. The analyses carried out by VUMOP, v.v.i. show that sheet erosion – or its combination with other types of erosion – is the prevailing erosion type in the CR (VUMOP, v.v.i. 2014), see Fig. 18.

As the canopy cover becomes more closed, the erosion control effects of the crops increase. However, with some crops the problem remains even when their canopy is fully developed and the precipitation is relatively low. From this perspective, maize (even fully grown) and potatoes are the most problematic crops.

In the overwhelming majority of erosion events (detected or modelled in LaPlaNt), the GAEC standard is not found to have been violated, which proves that its setting is excessively mild and confirms the necessity of its adjustment, especially regarding the inclusion into erosion risk categories as related to the specification of parameters for determining the erosion risk degree.

A prime example of what has been said is the sowing of headlands (see Fig. 19), which cannot stop erosion on the land block, not even if this block has a smaller area than the limiting 35 ha or is classified as medium erosion risk.

Fig. 18: Sheet erosion on vast land blocks Photo: P. Fučík

Another measure to control erosion and water pollution from agriculture is the conversion of stretches of arable land into grassland, the so-called greening. Green payments currently account for 30 % of direct payments (approx. 2,000 CZK / ha). The conversion of arable land to grassland is not only a measure to limit erosion but also to reduce the leaching of nitrogen and pesticides from soils both by surface runoff and agricultural drainage systems. As found out in the LaPlaNt project (Zajíček et al. 2016 – article *Úroda*), large-scale conversion to grassland brings about reduction in turnover and profit of a farming company and its greater dependence on subsidies. For these reasons, it is necessary to use the conversion of arable land to grassland on intensively farmed land as a specifically targeted measure in small areas only. It is further indispensable to perceive the non-production functions of grassland (water quality improvement, water retention increase, etc.) also as a public service and, with this in view, to set up the subsidy schemes relating to the creation and management of soil and water conservation measures at the landscape level.

Technical erosion control measures (furrows, ditches, balks, dry ponds, etc.) are frequently implemented through the comprehensive land consolidation process (LC) as part of the proposal and implementation of the so-called plan of common facilities, which, in addition to the road network, includes measures for flood control, water retention and quality.

However, the LC process is often regarded as lengthy and demanding from the administrative point of view by its participants; occasionally it is complicated by entities pursuing their own interests and there is a significant delay between the completion and real implementation of the measures.

Fig. 19: GAEC fulfilled, erosion continues… (photo by VUMOP, v.v.i.)

Within the completed Rural Development Programme of the Czech Republic 2007–2013, only 9 % of all the proposed measures were implemented as part of LC from 1995. Only as little as 7 % of the proposed erosion control measures and 10 % of the proposed water management measures were implemented. However, considerable length is common for the process of planning and projection of LC in the Czech Republic. This is due to the need for coordination among land use planning, renewal of the land register, changes in land estate ownership and investment activities. It usually takes 7–10 years from the initiation of the administrative proceedings and the preparation of LC until the final inspection of the soil conservation or water management measure. Apart from the funding, their implementation largely depends on the promotion of landscape features and conservation measures as a public interest among the LC stakeholders, particularly farmers, land owners or e. g. watercourse managers.

It is therefore necessary to promote a shift in mindset and behaviour in the CR from business-model landscape management to a more responsible and sustainable land management regime. According to the results of our survey as well as other experience, more appropriate and specific awareness raising campaign would be useful including expert as well as practice-focused workshops common for farmers and public administration workers from lower ranks to senior officials (Fučík et al. 2016). From the perspective of agricultural land and landscape protection, it is necessary, in addition to making shifts in the LC processes, to change the GAEC standards on water and soil management at landscape level, as they are insufficient in the CR at present. At the same time, it is imperative to more conveniently set up the relevant subsidy system as a stable and long-term public interest support in the form of public service based on rigorously defined management conditions.

Norwegian policy and practice regarding mitigation measures in agricultural landscape

In Norway, phosphorus (P) is shown to be the limiting nutrient for eutrophication in lakes and streams and the main policy focus in Norway are on reduction in P loading. The most important mitigation measures targeted on P non-point sources from agriculture are management of manure, changed soil tillage and grassed buffer zones along open water and sedimentation ponds (Bechmann et al., 2016). Despite the introduction of numerous measures in recent years, problems with eutrophication still remain.

The implementation of mitigation measures consists of general production grants, legislation on manure management and subsidies. The regulations relating to production subsidies include a number of environmental standards farmers must meet to be entitled to the subsidies, including pesticide journal, fertiliser application plan, and two-meter buffer zone along water ways. A farmer who does not comply with the requirements may lose part of the production subsidies. Arable farmers must carry out a plan for fertiliser application to avoid a surplus of nutrients, and there are rules limiting the number of livestock that may be kept per unit area of land.

Fig. 20: Agricultural landscape in Norway

There are two systems of subsidies for environmental measures in agriculture to encourage farmers to reduce erosion and P-losses. The one system is meant to solve specific regional environmental challenges (Regional Environmental Programme, RMP) and the other system is for special measures requiring more long term investments and maintenance (SMIL). In the SMIL system farmers can for example apply for subsidies to establish constructed wetlands or sedimentation ponds, hydrotechnical installations, waste water treatment facilities or re-open culverted streams. Both investment and maintenance may be paid by subsidies. The local county authorities are responsible for these schemes.

Practices that may be eligible for subsidies in RMP include:

- Changed tillage, stubble/minimum-till rather than bare soil during the winter
- Buffer zones along streams and lakes
- Grassed water ways
- Grass on flood areas
- Catch crops
- Manure application in spring and growing season

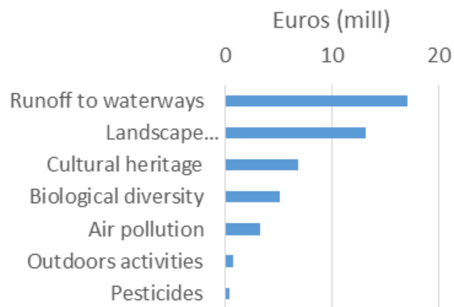

Fig. 21: Distribution of subsidies in the RMP program in 2014 (Snellingen et al., 2015)

The county governor authorities can adjust measures to suit regional conditions like the agricultural production system, the main environmental problems in the county, i.e. erosion risk and pollution level. Since 2005, the agri-environmental program has been regional in nature, which means that the county governor is responsible for the management of these schemes and have the freedom to choose level of payments, adjust measures and implement new measures. However, these decisions are made in collaboration with NGOs, farmer organizations, municipalities and the state. In 2014 around

205 million NOK was given in subsidies to environmental measures.

Fig. 22: Sedimentation pond in Rogaland County

Implementation and effects of measures

Around 2.7 % of Norway is agricultural land and in 2013, the area of cereal production constituted 0.30 mil. ha, or 29 % of the total agricultural area in use. Soil tillage methods in cereal areas are highly important for the risk of erosion and the risk of P losses from these areas to the water bodies. Autumn ploughing has been shown to increase both erosion and P losses (Bechmann et al., 2011). The highest P losses have been registered from winter wheat fields, which are ploughed before drilling, but also autumn ploughing of spring cereals causes the high P losses. The traditional soil tillage method until 1990 was autumn ploughing. During the period from 1990 to 2002 Norwegian Statistics collected data on soil tillage through "Selected counting's for agriculture". Through this period the autumn ploughed area was reduced from 82% to 43% of the cereal area. Subsidies of NOK 164 million were given to change tillage methods, including catch crops and grassed water ways in 2013 (Regional environmental program).

Mitigation measures, such as catch crops and grassed water ways received special subsidies from autumn 1991. In 2012, subsidies were given for 424 km grassed water ways, 1232 km vegetated buffers and 5770 ha of grassed environmental area. The total subsidies for this were NOK 23.3 million. The area with catch crops reached its top in 2002 covering in total 35 000 ha with subsidies amounting NOK 37.7 million. Later this area has gradually declined and was in 2012 4400 ha. The amount of subsidies per area decreased simultaneously. In 2012, subsidies were given to catch crop in cereal areas, early potatoes, vegetables and others.

Establishment of sedimentation ponds and constructed wetlands are nature based systems to reduce runoff of soil particles and P. Subsidies for establishment of sedimentation ponds and constructed wetlands are part of the SMIL-system. In 2012, NOK 3.1 million was given in subsidies for establishment of 38 new sedimentation ponds and constructed wetlands. During the period from 1994 to 2012 subsidies for in total 941 sedimentation ponds and constructed wetlands has been given. The number is especially high in the Rogaland County. To reduce erosion and nutrient runoff, SMIL-subsidies are also given for hydrotechnical installations. In 2012, NOK 26.8 million was given to 592 hydrotechnical installations. The counties with the most arable land receive the most money for hydrotechnical installations.

Cost-effectiveness of measures

The cost-effectiveness of mitigation methods is an important criterion for selection of mitigation methods to be recommended. The cost-effectiveness of various soil tillage methods for different counties and areas in Norway are analysed in Refsgaard et al. (2013). A key message to policy makers was the very large variation in cost-effectiveness due to variation in erosion risk, with the best cost-effectiveness obtained by implementing mitigation measures on high risk areas of erosion. An analysis of farmers' gross margins for different tillage practices in different counties in Norway, found that changing tillage most often reduce farmers' gross margin, but there are significant variations in these costs. The costs of reducing P losses by 1 kg ranged from NOK 2 000 - 3 000 on areas with low erosion risk, and NOK 200 - 300 on land with high erosion risk. As such the subsidies provided for changed tillage on areas with low risk do not cover the costs for the farmers' changed tillage. Nevertheless, the primary aim is to successfully cope with the high-erosion risk areas.

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