The project has been funded with the support of European Commission within ERASMUS+ program

Flood management of mountain catchments

Educational material for students

Project office: Ks. Janusza 64, 01-452, Warsaw, Poland http://odyssey.igf.edu.pl edukacja@igf.edu.pl

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Introduction

The following educational package consists of two parts. The first contains basic information about floods, as well as ways of managing mountain river catchments, which aim to prevent floods as well as minimize losses in extreme situations.

In the second part you will receive tips on how to directly prepare for the debate, in particular how to prepare arguments supporting or contradicting the following resolution:

Small retention measures for flood protection of mountain river catchments are more effective than construction of a large dam reservoir.

FLOODS

The number of floods has been increasing steadily in recent years, they are more rapid and the losses are higher.

In recent years, the losses due to floods in the upper Vistula catchment reached billions of Euro. Floods in 1997 and 2001 brought losses of almost 750 million euros in this region, and floods in 2010 - over 1 billion euros and the amounts above covered only losses in municipal infrastructure of local government units and hydrotechnical infrastructure managed by regional water management boards and voivodship management boards of drainage and water facilities.

Table 1. Flood potential indicators (according to data from 2006).

Region	Annual rainfall		Annual outflow		Area		Population rate
	[10^6 m^3]	[%]	[10^6 m^3]	[%]	[km^2]	[%]	[persons/ km^2]
Poland	189 573	100,0	62 000	100,0	312 685	100,0	122
Upper Vistula catchment in Poland	30 183	15,9	14 500	23,4	48 035	15,4	175

Think and answer the following questions:

1. Does the amount of annual precipitation in the upper Vistula catchment differ significantly from the national average?
2. How can we explain much higher annual outflow from the upper Vistula catchment than the national average?

Table 2. Damage in the hydrotechnical infrastructure and river banks during the flood in 1997.

Region	Hydrotechnical infrastructure		River embankments		Area	
	[number]	[%]	[km]	[%]	[km]	[%]

Poland	2 861	100	721,4	100	9 065,9	100
Upper Vistula catchment in Poland	2 169	75,8	198,7	27,5	5 604,4	61,8

3. How can we explain the differences in the losses related to hydrotechnical infrastructure compared to the damages of embankments?

Table 3. Flood damage of arable crops, as well as in transport infrastructure and buildings as a result of the 1997 flood

Region	The area of flooded arable land and grassland		Roads				Bridges				Buildings	
			Of national importance		Of provincial importance		Of national importance		Of provincial importance			
	[ha]	[%]	[km]	[%]	[km]	[%]	[km]	[%]	[km]	[%]	[no]	[%]
Poland	520 633	100	1 247	100	13 186	100	304	100	3 730	100	72 267	100
Upper Vistula catchment in Poland	143 739	27,6	762,6	61,2	7 421,4	56,3	123	40,5	2 128	57,1	20 601	28,5

4. Why were the losses in agricultural crops, road infrastructure and buildings in the upper Vistula basin so significantly greater than those calculated for the entire territory of Poland?

When we are dealing with a short-term increase of the water in the river (water flows outside the river bed), which causes the risk of damaging the infrastructure (houses, roads, transmission lines, bridges, etc.), we call it **flood**. In the annual water flow in the river, we also observe a less dangerous increase of the water level, which does not threaten the infrastructure, which we call **high-water stage of the river**.

A catchment, like a river basin, is an area from which surface water flows into a river. The basin is the entire area drained by a given river. The catchment area is part of the river basin. When we talk about the risk of flooding in the catchment area of a given river, we mean possible losses in the land area drained by a given river.

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PREPARATION OF ARGUMENTS: USEFUL INFORMATION

Info card 1
What influences the high-water stage in rivers? Both the natural conditions and the land use introduced by humans have an impact on the flow discharge in rivers, and thus on the formation of high-water stage that can lead to flooding. The most important factors are: 1. **Climate conditions**: annual precipitation, length of the winter period, melting processing, distribution of precipitation over time: summer precipitation (rain) and winter precipitation (snow). 2. **Geological and geomorphological conditions**: geological structure, morphology - degree of relief differentiation, (denivelations), slope steepness, soil types. 3. **Land use**: forests, agricultural and pastoral areas, urbanization - type and density of buildings. 4. **Hydrotechnical protection of the catchment area**: small retention measures, afforestation, proper agricultural management, small water reservoirs (damming for mills, sawmills, local hydroelectric power plants), hydrotechnical solutions: anti-rumbling thresholds, polders, dry reservoirs, polders, small retention reservoirs (less than 5 million m^3 of volume), multi-purpose reservoirs (over 5 million m^3).

Info card 2
What is precipitation? What happens to rainfall? **Precipitation** is the product of condensation of water vapor in the air that falls from the clouds and reaches the Earth's surface. They can be in the form of a.o. rain, snow, hail or snowballs. **Actual (measured) precipitation** is the volume of rainwater that falls per unit area of the ground per unit time. Most often it is given in mm of precipitation, less often in l/m^2 or in m^3/km^2. Keep in mind that: **1 mm of precipitation = 1 l/m^2 = 1 m^3/km^2** Not all rainfall has to cause swelling (high-water stage) and flooding. Before rainwater flows into a river, it may become stuck in the soil, plants or evaporate along the way. The individual elements of the rainwater cycle are: 1. **evaporation** - part of the water evaporates very quickly and comes back to the atmosphere; 2. **plant reception** - part of the rainfall remains on plants; 3. **infiltration and ground retention** - part of the rainfall soaks into the ground and supplies groundwater;

4. **surface retention** - part of the precipitation retaining in the terrain surface irregularities (natural and artificial);
5. **surface runoff** - part of the rainfall flows immediately on the surface to the nearest river.

When planning flood protection measures, one should remember that the more water is retained in the catchment area, the lower the possibility of a flood in the river. The surface runoff can vary from ~ 100% for artificially sealed surfaces - asphalt roadways and squares, house roofs, etc., to ~ 0% for vegetated areas or very well-drained soils, e.g. gravel. Surface runoff increases four times when changing the forest vegetation cover to a wasteland without vegetation cover. Appropriate changes in the land use of the catchment area are therefore the most important factor influencing the size and nature of water outflow, and thus the flood phenomena.

Info card 3

Small retention measures, including nature-based solutions in the catchment area - pros and cons

The term "small retention" is used to describe both technical treatments performed within the river bed, as well as a number of land use treatments in the catchment area.

Hydrotechnical measures include among others:

- construction of thresholds reducing the slope of the river;
- permanent protection of essential elements of infrastructure only (bridges, power lines, buildings);
- riverbed development of the catchment - construction of anti-rumbled tresholds and sediment traps on the sections of the upstream tributaries, full development of the bottom and banks of the middle sections, embankment of the lower sections.

Nature-based solutions include among others:

- afforestation of wastelands;
- changing the form of land use from agricultural to pastoral or further to afforestation;
- changing the form of agricultural management - slope blocking, cultivation procedures (plowing, planting) carried out in accordance with the course of contour lines;
- leaving floodplain polders in the valley bottom;
- creation of small retention reservoirs, e.g. fish ponds, damming for small power industry purposes;
- organization of small access roads in a way that minimizes the possibility of their transformation into flood outflow routes.

PROS	CONS
low direct costs of small retention measures, the possibility of spreading them over time;	no immediate effects of the measures; they are only visible in the long term;

▪ no social costs related to the relocation of residential buildings; ▪ increasing the range of natural retention; ▪ increasing groundwater resources; ▪ improving the regularity of the outflow; ▪ reducing the height of flood waves; ▪ compliance of the proposed development solutions with the trends of transition from extensive farming to tourism development (agritourism); ▪ increasing the area of forest land as "green lungs"; ▪ reduction of soil surface degradation; ▪ limitation of sediment transport; ▪ increasing local floodplains above the thresholds reducing the slope of the channels; ▪ development of alternative forms of farming (fish ponds instead of extensive farming); ▪ the possibility of developing sources of "green energy".	▪ the need to conduct extensive information and education activities - a number of measures apply to private land, hence the need to convince their owners to change the way of development. Often, information and education activities are of limited effectiveness. ▪ flattening of the flood wave profile - flood waves are lower, but the duration of flood increases; ▪ limited effectiveness in the case of extreme phenomena.

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Info card 4

Hydrotechnical solutions, including construction of a large dam reservoir - pros and cons

The hydrotechnical solutions include a number of activities that interfere with the natural environment. It includes the following elements:

1. **construction of large dam reservoirs**, which uses large area of the catchment;
2. **construction of artificial channels** - covering the whole cross-section of the river bed with stone pavement or concrete coating. It causes the quicker flood wave run-off (short time with high-water stage). It results also in taking the rock debris and transporting it through the strengthened section, and then settling them below the constructions.
3. **solid construction of the bottom and banks embankments** - these are mainly local constructions built in order to protect residential areas and roads.

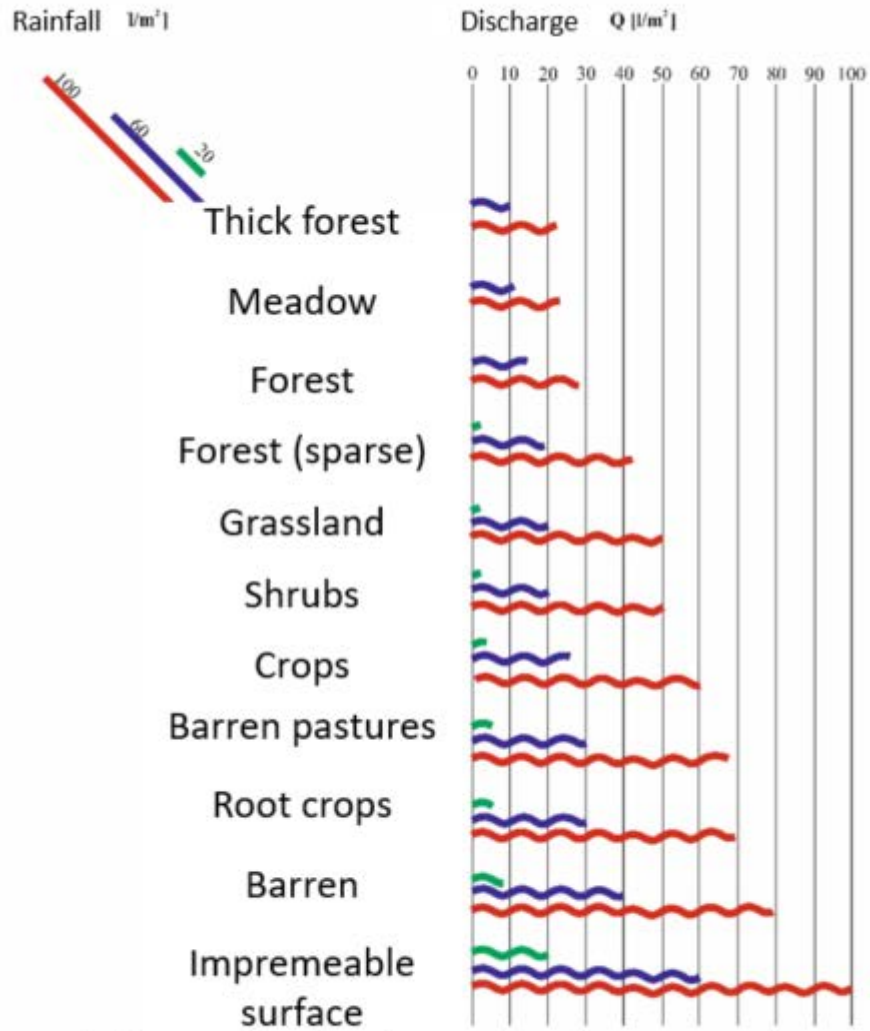
PROS	CONS
precise determination of the reaction time of hydrological processes in the catchment area; the possibility of determining the height and speed of the flood wave flow on the basis of observations at a measuring point (rain gauge or water gauge), located in the catchment area; effective protection of the parts of the catchment area below the reservoir against floods (for the assumed flood wave frequency); the possibility of using the reservoirs for recreational purposes; the possibility of building a hydroelectric power plant and producing "green energy" from renewable sources; shortening the flow time and lowering the flood wave below the reservoir.	high direct costs of reservoir construction, high costs to be incurred within a short time; elimination of economically used areas designated for flooding; high costs of relocation of inhabitants of areas intended for flooding; very high social costs of relocating settlements and single farms existing in the floodplain; deposition of sediment in the reservoir limits its water storage functions in a relatively short time (several dozen years); increasing abrasion process and sediment transport below the reservoir (the reservoir holds up to 100% of the dragged sediment and up to 70% of the suspended sediment), which increases the transporting energy of the river.

Info card 5

What is the retention capacity of various land use forms?

Various forms of land use have different capacity of water retention. This capacity differs also with the amount of precipitation. The more rainfall, the highest runoff.

The most effective in storing water after even a heavy rainfall is a thick forest. Depending on the intensity of the rainfall, a thick forest keeps 80-100% of water. The worst surface for the water retention is an impermeable surface (e.g. asphalt) , which let to even 100% of water runoff in case of heavy rain.



influence of various forms of land management on its retention capacity and the amount of runoff

(Bayerisches Landesamt für Wasserwitschaft, Spectrum Wasser !, Hochwasser 1998)

Info card 6

Impact of selected small retention measures on water resources and the environment

There are many small retention measures. Examples of measures are summarized in the table. For each method, its impact on surface water, retention in soil, ground water, landscape, biodiversity and water quality was assessed and threats were determined.

Legend: +++ significant impact, ++ moderate impact, + minor impact, +/- negative impact or no effect

Measure	Impact on						Threats
	surface water	retention in soil	ground-water	land-scape	biodi-versity	water quality	
Afforestation of agricultural land	+	+/-	+/-	+++	+++	++	reduced groundwater supply
Mid-field afforestation (reducing wind erosion)	+	++	+	+++	-/+	+	introduction of alien species
Agrotechnical solutions (improvement of soil structure)	++	+++	++	+	+	++	over-intensification of agriculture
Agrotechnical solutions - collecting water on farmland (small ditches, low dykes at the edge of the fields)	+++	+++	+++	+/-	++	+++	reducing the frequency of spring floods
Buffer zones along watercourses and reservoirs	+	+	+	++	++	+++	reducing the area of grasslands and arable fields
Controlled outflow from drainage systems	+	++	+++	+	+	+++	the possibility of excessive soil moisture
Construction of micro-reservoirs in ditches	+++	++	++	++	+++	++	excessive humidity of arable fields

Infiltration tanks and ditches	+	+	+++	+	+	++	groundwater pollution
Dry reservoirs / polders (river valleys used for agricultural purposes)	+++	++	+	+	++	+	periodic destruction of crops, excessive humidity / overdrying
Restoration of meanders, construction of dug reservoirs in the river valley (water retention during high spring flows)	++	+	++	++	++	+	loss of agricultural land
Construction of reservoirs at the outflow of drainage systems	++	+	+	++	++	+++	loss of agricultural land
Construction of small (damming) reservoirs on rivers	+++	++	++	+	++	++	destruction of valuable ecosystems, problems with fish migration
Tanks dug in local depressions	+	++	+	+	++	+	destruction of valuable ecosystems
Rebuilding small ponds	++	++	+	++	+++	+++	changing the ecosystem to a less valuable one
Renaturization of rivers (restoring meanders)	+++	++	+	+++	+++	++	flooding agricultural areas
Restoration of wetlands and peat bogs	+++	+++	++	+++	+++	++	excessive limitation of the supply of water courses
Anti-erosion treatments (various)	++	+	++	++	++	++	changes in ecosystems

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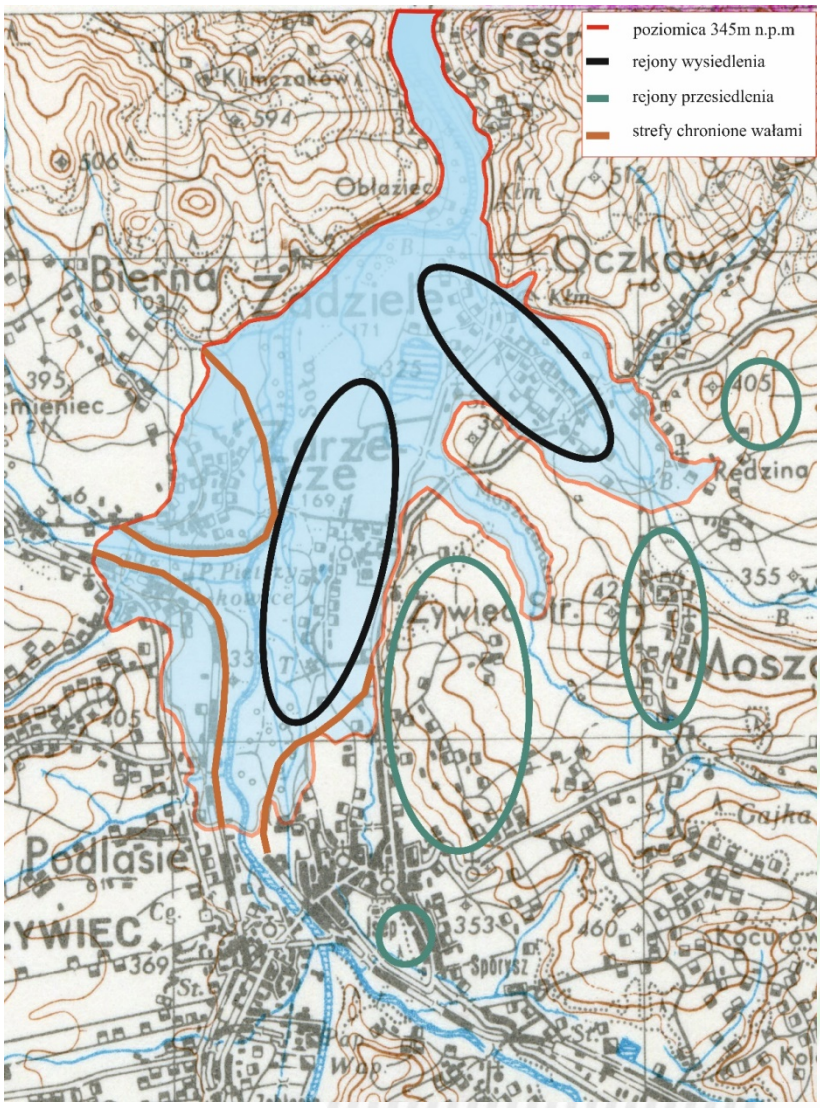
Story card 1

How did the Żywiecka Valley in Poland change after the dam in Tresna and the Żywiec Reservoir were built?

The Żywiecka Valley is a flat and agricultural area. At the beginning of the last century, in the vicinity of the Soła River there were many agricultural villages, e.g. Stary Żywiec, Zarzecze and Zadziele. The construction of the dam and reservoir changed the lives of around 3,800 people who were resettled. The project for the construction of the reservoir envisaged flooding the central part of the Żywiec Basin, which involved the necessity of resettlement of inhabitants of these towns and providing them with the opportunity to rebuild farms in the areas next to the reservoir. In most cases, it was not possible to restore large farms, but only residential buildings. It forced the local population to retrain from agriculture to industry.



The construction of the dam also envisaged the launch of a hydroelectric power plant there. The 21MW Tresna hydroelectric power plant produces electricity from renewable sources. The dam was built at the beginning of the 1960s. In parallel with the construction, the resettlement of inhabitants and the liquidation of residential buildings in the area designated for reservoir was underway. The construction of the dam was completed in 1964. Two years later, the reservoir was filled in. The map presents the range of maximum water level. The northern part of Żywiec and the part of Zarzecze that could potentially be flooded are now protected by dikes. Ensuring safety in these areas requires constant maintenance of the dikes and drainage system for areas behind them.

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Story card 2

Sediment deposition in the Żywiec Reservoir

The Żywiec Reservoir was built after the construction of a water dam on the Sola River in 1964. The dam in Tresna has a height of 39 m, and the reservoir reached a maximum depth of 26.8 m. Its total capacity is 94.6 million m^3.

One of the functions of the reservoir is flood protection of the lower parts of the basin by stopping excess water flowing during floods. River waters carry sediment from the erosion of the river basin. 90% of these deposits are left in the reservoir, which gradually reduces its volume.

The satellite photo shows the part of the reservoir into which the river flows. When the water reservoir was launched, water in the reservoir reached the bridge visible at the bottom part of the picture. After approx. 50 years of operation, the sediment deposited by the river covered approx. 15% of the reservoir's area.

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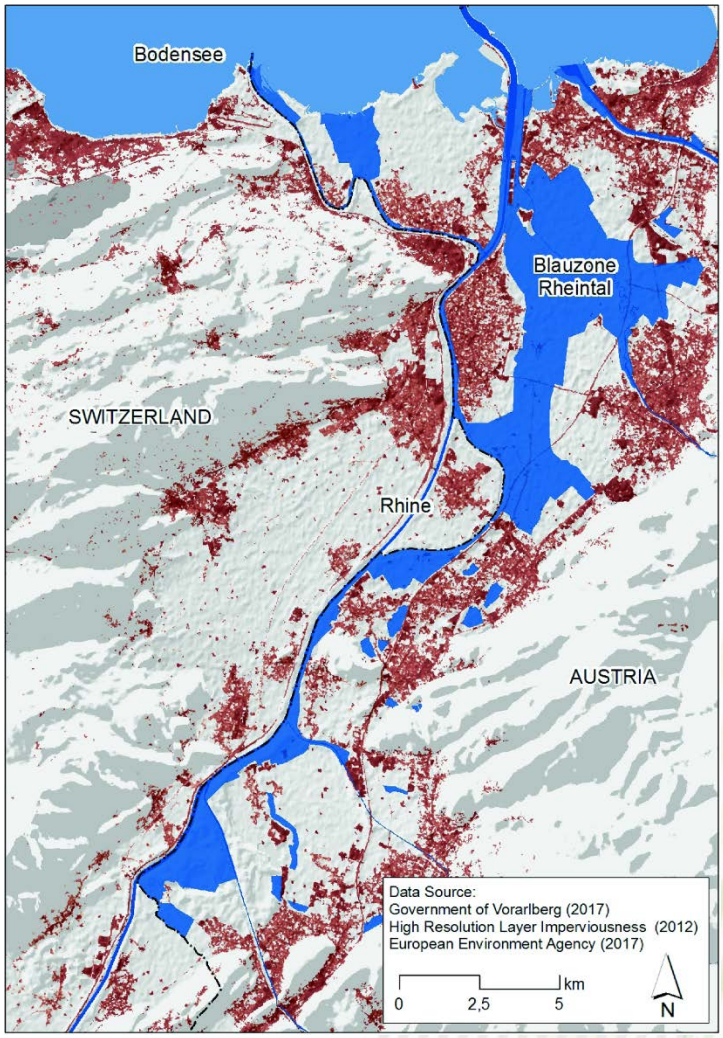
Story card 3

Alternative flood management – case study from Austria



In 2005, Alpine regions in Austria and Switzerland suffered a major flood event. Vorarlberg, the westernmost province in Austria, was particularly affected, as some regions experienced the highest discharge levels in more than a century.

Total damages to households, businesses, infrastructure, etc., amounted to more than EUR 180 milion.

In 2013, following another large flood event, the Vorarlberg state government issued the "Blauzone Rheintal", a regional spatial plan that designates flood runoff and flood retention areas along the Rhine and its tributaries.

The main aims of the spatial plan are:

- ***Protect settlement areas*:** Existing settlement areas are protected against flooding. To minimize the further increase in damage potential, zoning for building land in the designated flood hazard areas is severely restricted.
- ***Preserve open areas for flood retention and flood discharge*:** To reduce flood peaks, existing and potential flood retention areas are kept **free of building development**. These areas particularly include **agricultural and forest areas** with low damage potential, which may also be temporarily flooded in extreme events, as when there is a need to accommodate storm water to prevent a dike breach.

The "Blauzone" predominately includes areas with low damage potential, such as agricultural or forestland. Highly vulnerable areas, meaning developed areas, as well as land zoned for building were specifically excluded from the spatial plan.

Zone areas located within the "Blauzone" are so-called open space reserve areas. This means that no development is permitted in those reserve areas with the exception of enlarging existing agricultural facilities.

Source: Löschner L., Seher W., Nordbeck R., Kopf M. (2019) Blauzone Rheintal: A Regional Planning Instrument for Future-Oriented Flood Management in a Dynamic Risk Environment. In: Hartmann T., Slavíková L., McCarthy S. (eds) Nature-Based Flood Risk Management on Private Land. Springer, Cham.

Preparation for the debate

After reading the materials presented, you can proceed to directly prepare the arguments for the debate. Below are a number of questions. Answers to them can be good arguments for discussion. Some of them strongly support the thesis, others will help in refuting it. Some arguments are debatable and can be used by both sides.

Task. 1

Answer the following questions. Write answers that are also arguments for discussion in the appropriate place in the table (Worksheet No. 1).

Question card 1	**Question card 2**
What is the impact of small retention measures on the size of surface runoff?	*What difficulties can arise when planning small retention measures on private land?* *How can we deal with it?*
Question card 3	**Question card 4**
What is the effectiveness of small retention measures during very heavy rainfall or rapidly melting snow?	*Why is it important that afforestation corresponds to natural habitats typical for particular place (in terms of climate and altitude)?*
Question card 5	**Question card 6**
Field terracing consolidates networks of field roads. *How does it affect the surface runoff?*	*Terracing requires heavy vehicles, which enter the filed.* *How do they affect the ground retention?*
Question card 7	**Question card 8**
Do the costs incurred for small retention measures (e.g. afforestation) end after these works have been completed?	*What is the impact on rainfall runoff and retention in case of a change in land use from agriculture to tourist services?*

Question card 9	Question card 10
Does afforestation have only positive consequences? May farmers have claims for these actions?	*What is the impact of demographic change on the effectiveness of small retention measures?* *Does the transition from extensive economy to agritourism have only positive effects?* *How aging of farmers affects land use?*
Question card 11	**Question card 12**
How can adaptation of farms and local roads to the needs of agritourism change the water regimes of rural areas?	*Does the construction of anti-rubble dams in upper parts of rivers cause other effects (lateral erosion, increase in the amount of sediment and debris) that reduce the positive effects of such activities?*
Question card 13	**Question card 14**
How do anti-rubble dams constructed in the upper parts of rivers affect the transport of sediments and the flood risk?	*Do hydro-technical solutions become old? Does their effectiveness change over time?*

Division into PROPOSITION and OPPOSITION teams

Task. 2

You already have arguments that you can use during the discussion. At this stage, you will prepare yourself directly to formulate the argument in accordance with the assigned role and to justify and defend them. Try to predict which rebuttals the other team will use and prepare your answers to rebuttals. In order to do this, use worksheet No. 2.

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Flood management of mountain catchments:

Hydrotechnical versus nature-based solutions

Author of the original package: Dr. Jerzy Giżejewski
English version prepared by Dr. Agata Goździk

Institute of Geophysics
Polish Academy of Sciences

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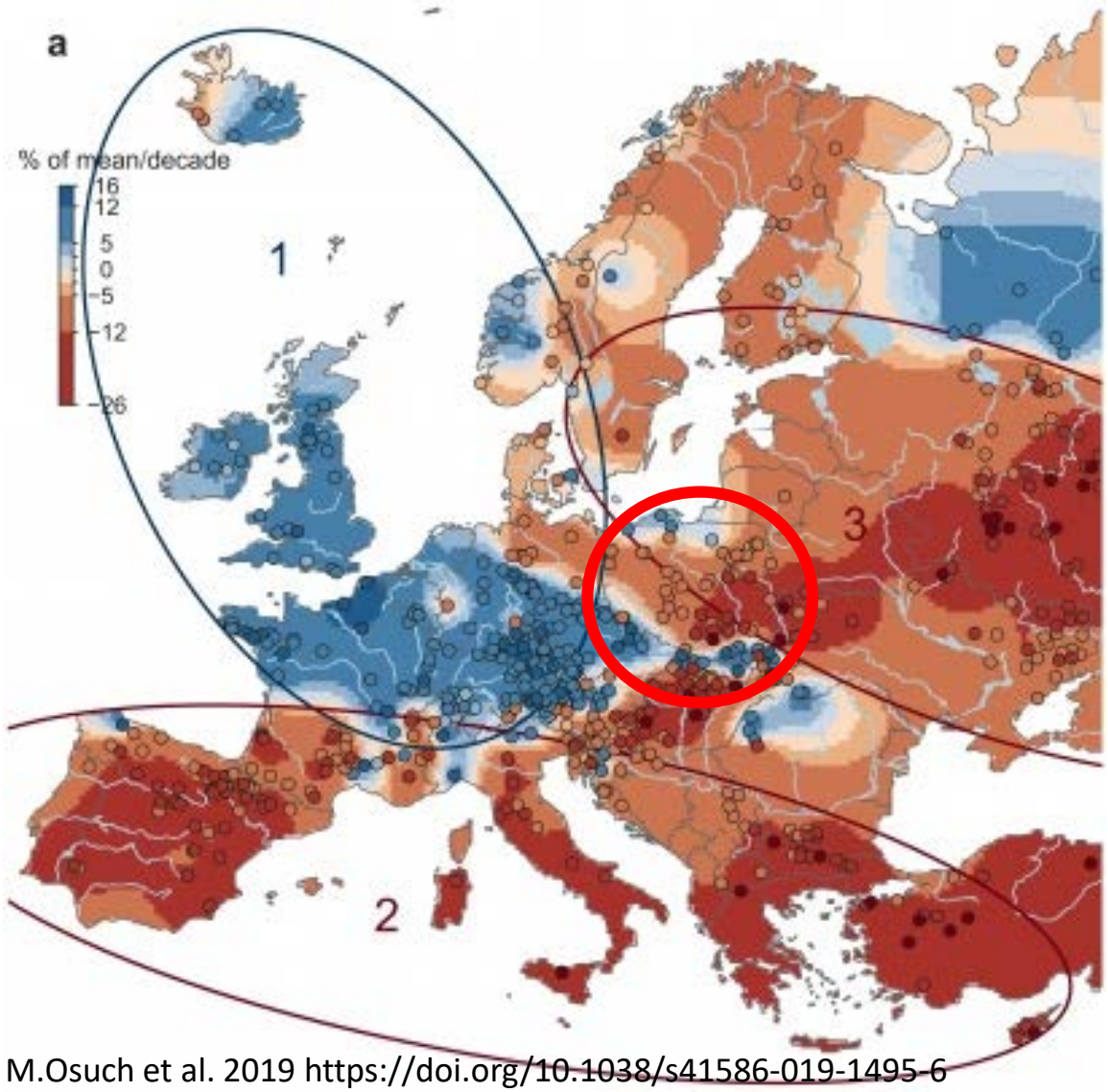


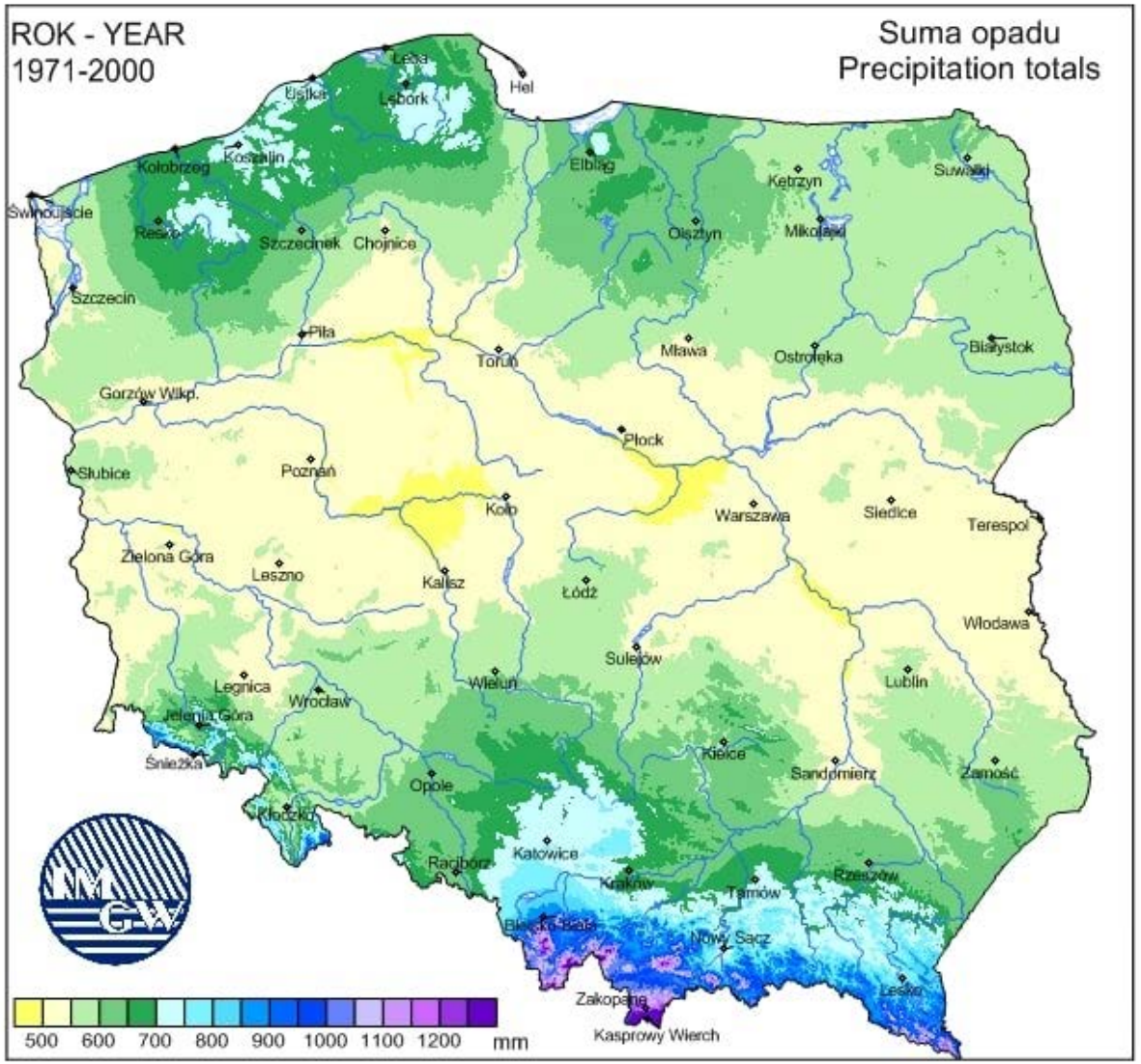
Source: M.Osuch et al. 2019 https://doi.org/10.1038/s41586-019-1495-6

Observed regional trends of river flood discharges in Europe (1960–2010).

Blue indicates increasing flood discharges and red denotes decreasing flood discharges (in per cent change of the mean annual flood discharge per decade).
Numbers 1–3:

1. Northwestern Europe: increasing rainfall and soil moisture.
2. Southern Europe: decreasing rainfall and increasing evaporation.
3. Eastern Europe: decreasing and earlier snowmelt.

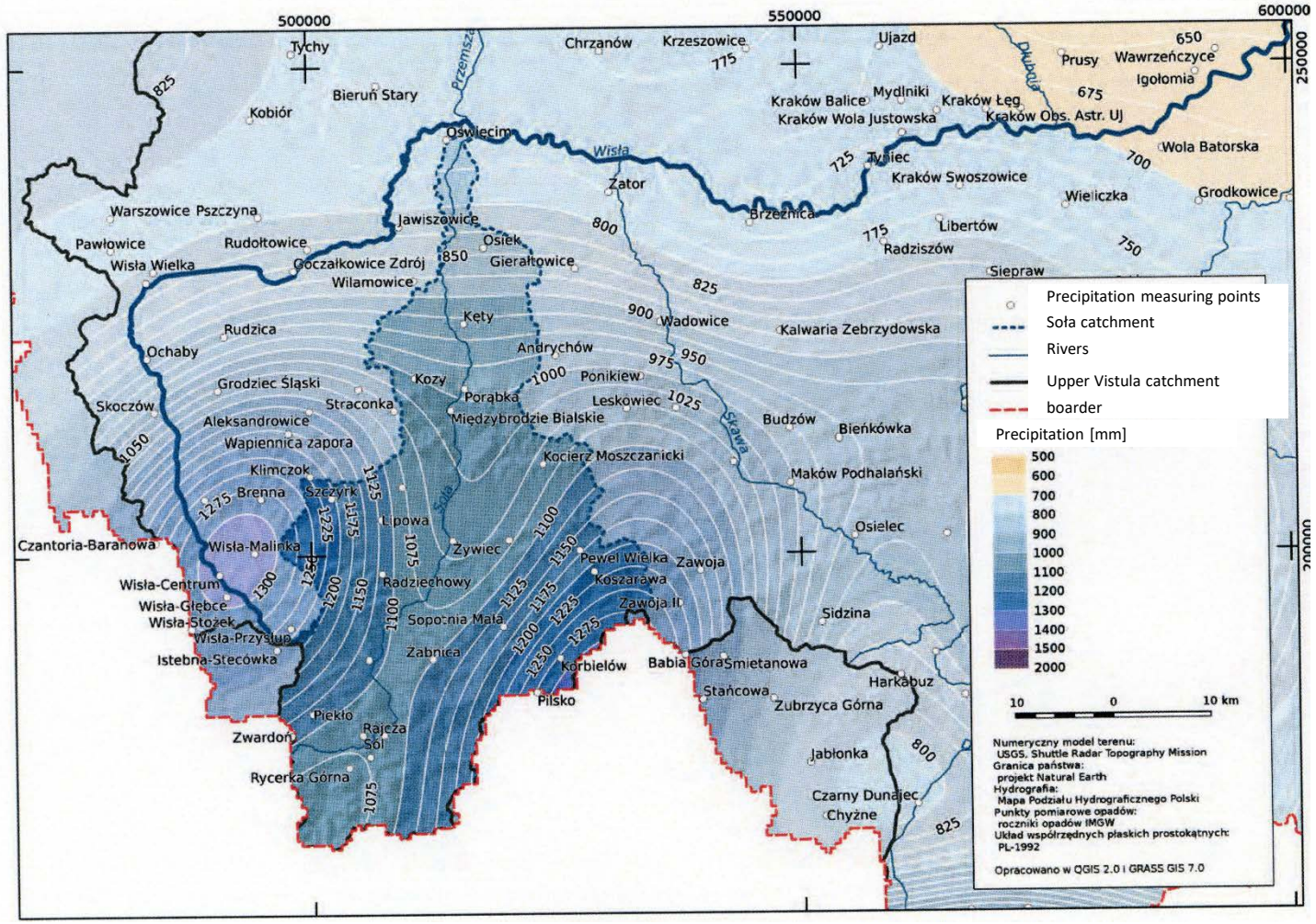
Poland – indicated by a red circle.



Annual precipitation in Poland

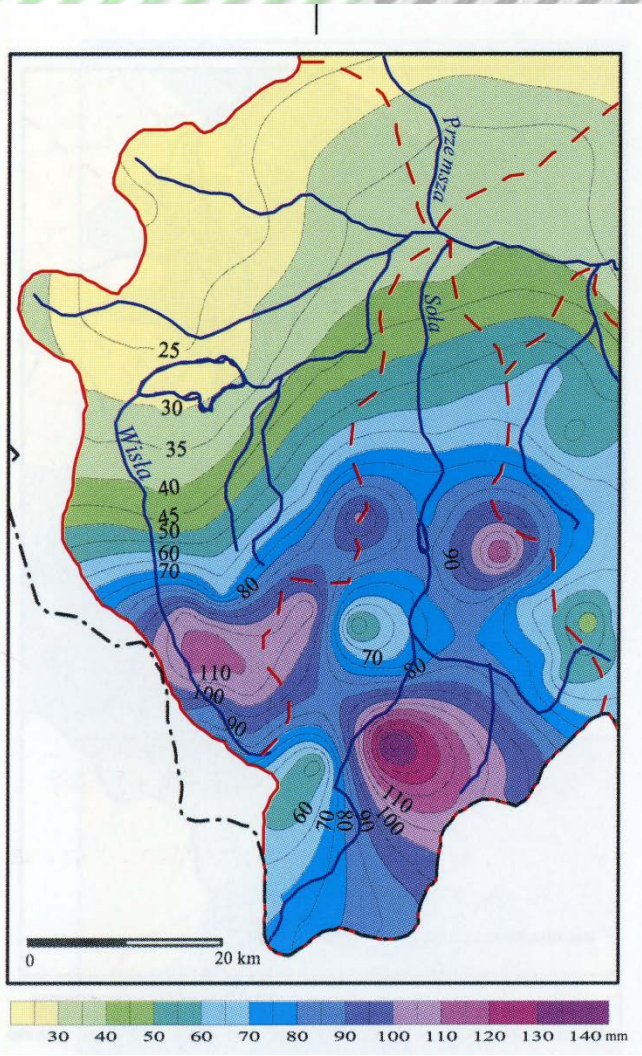
average over the years
1971-2000

Source: Cebulska et al. 2013



Average annual precipitation in the Soła river basin.

Source: Cebulska et al. 2013



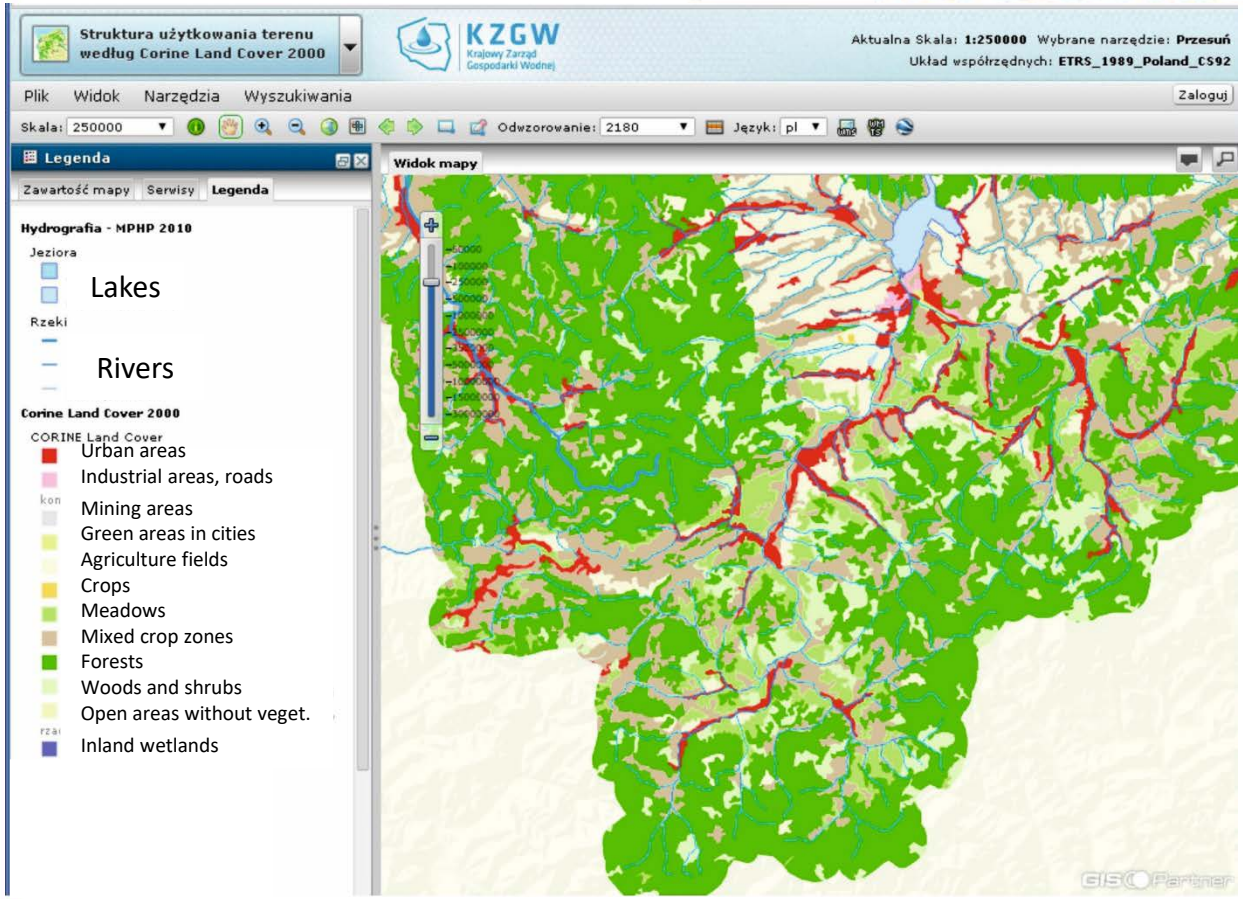
Isolines of daily rainfall on 8th July 1997 in the Small Vistula and Soła river basins.

Source: Grela J., Słota H., Zieliński J. 1997

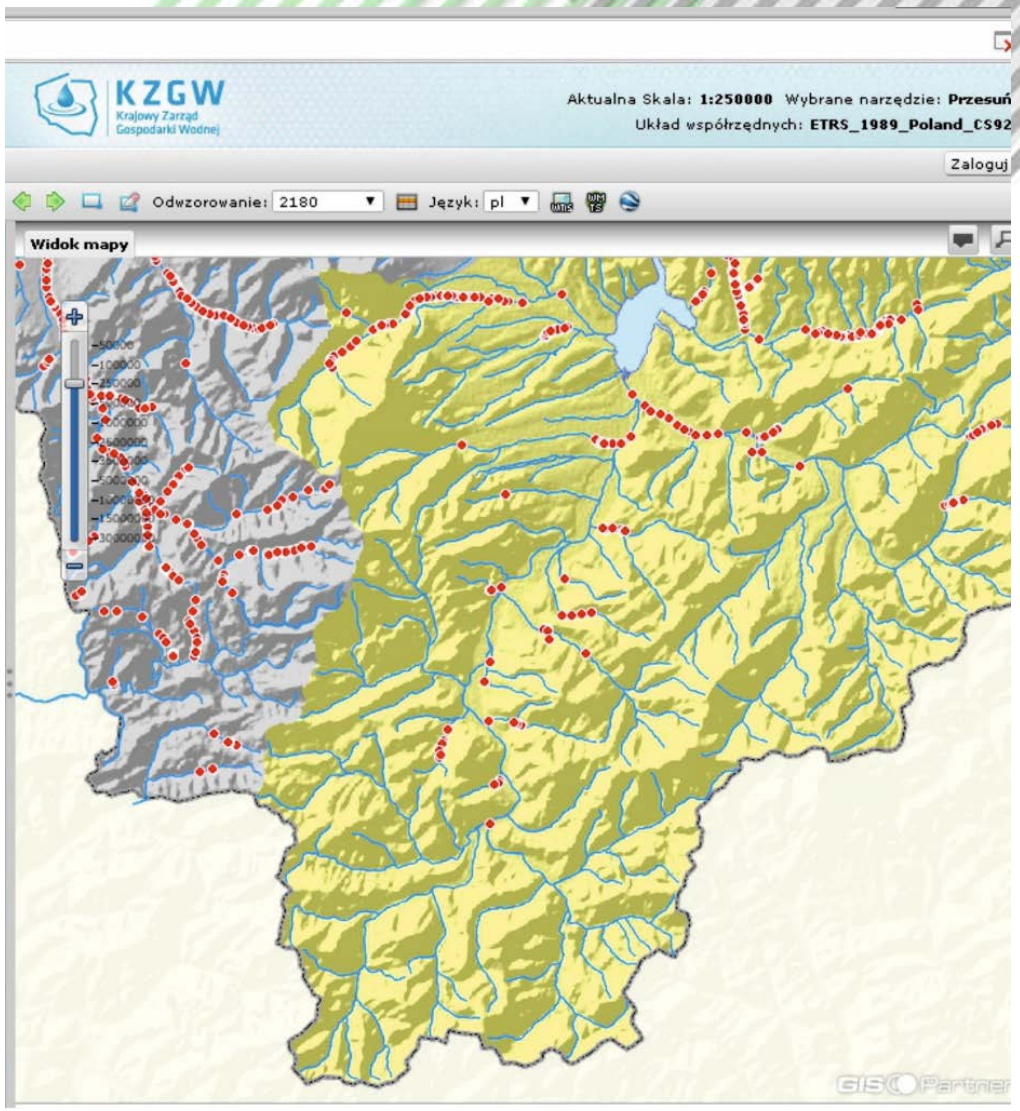
A damming treshold on the Soła river in Żywiec – left at lower water level, right – during flood.

Photo by J. Giżejewski

Photo by A. Giżejwska-Sabela



Map of spatial management in the Żywiec Valley



Żywiec Valley, map of damms (red dots)

Source: geoportal.kzgw.gov.pl/map/

Alternative flood management – case study from Austria

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Alternative flood management – case study from Austria

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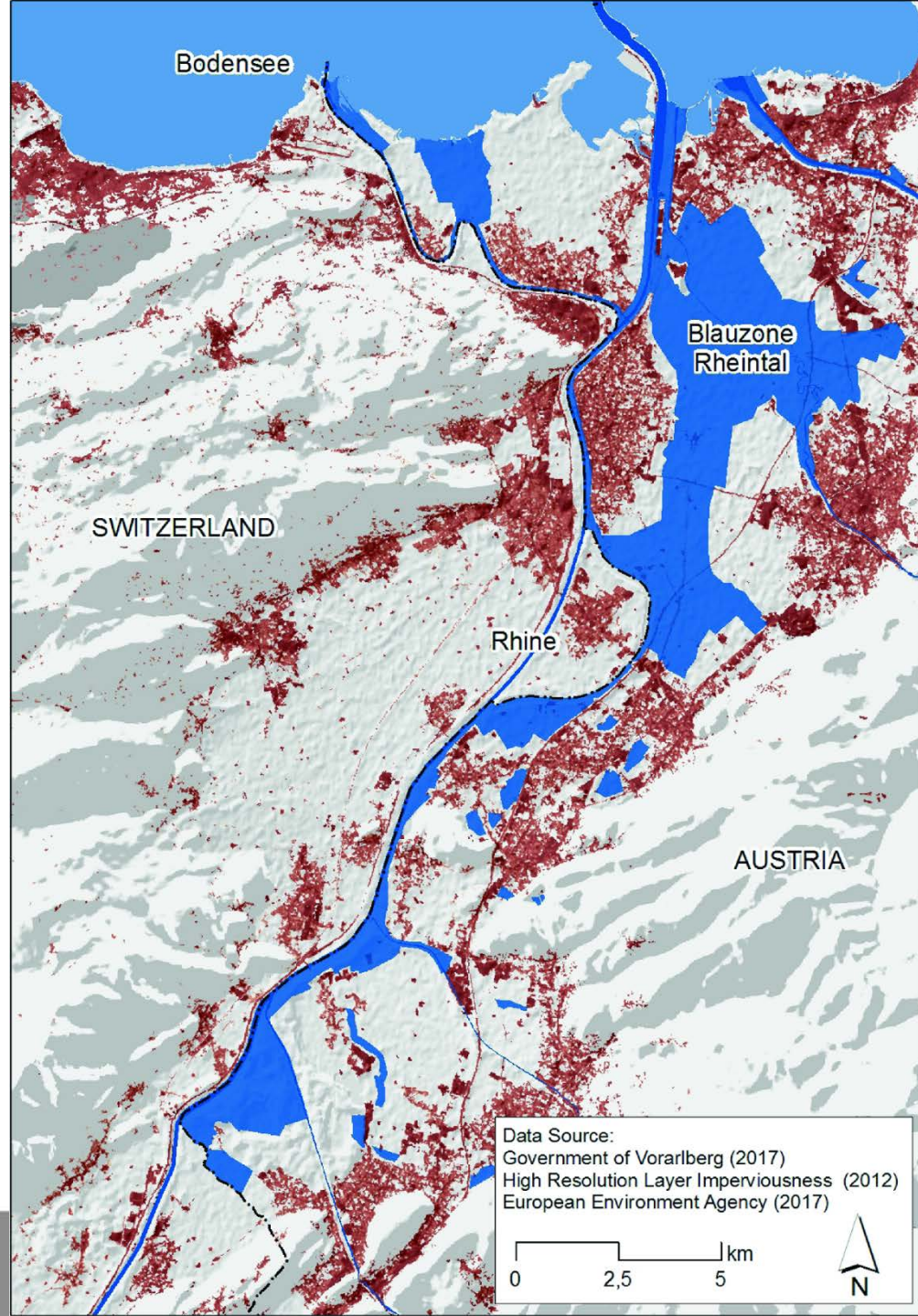
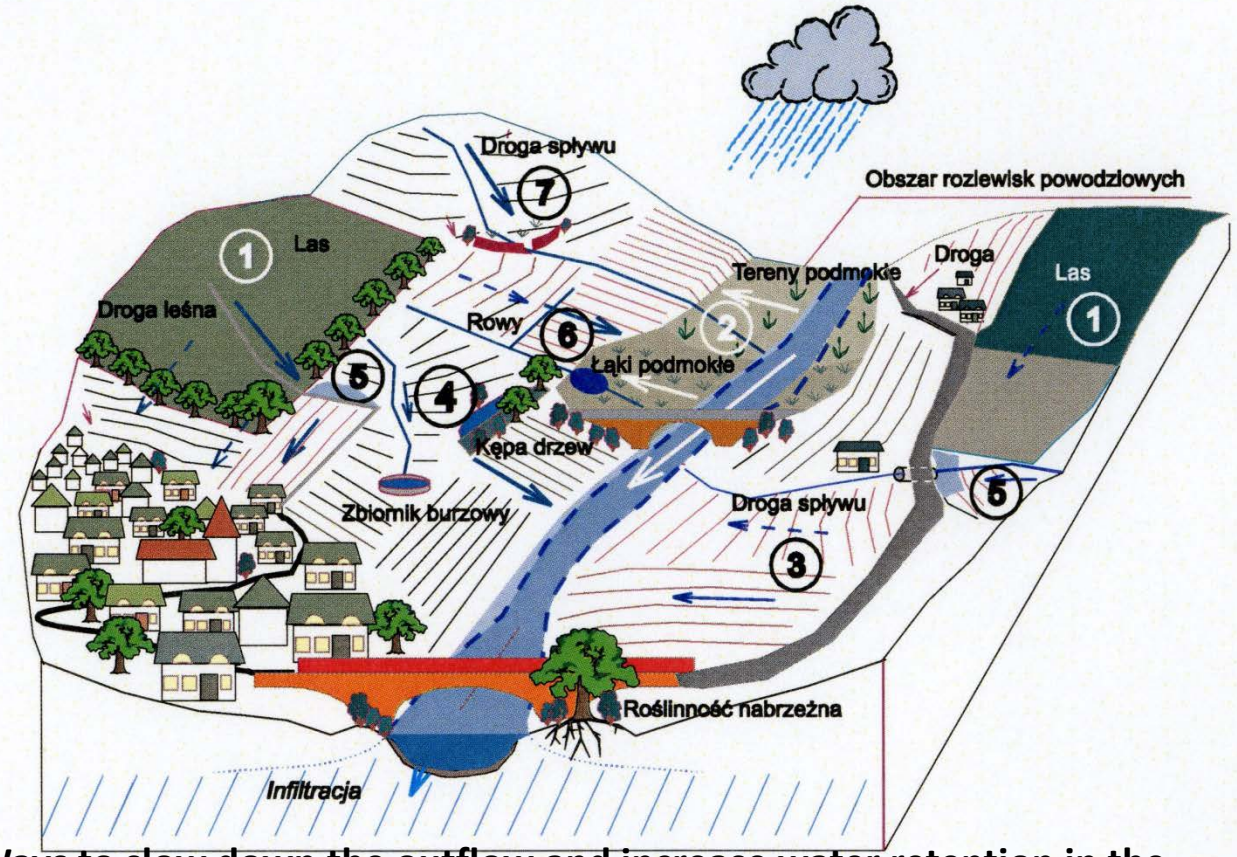
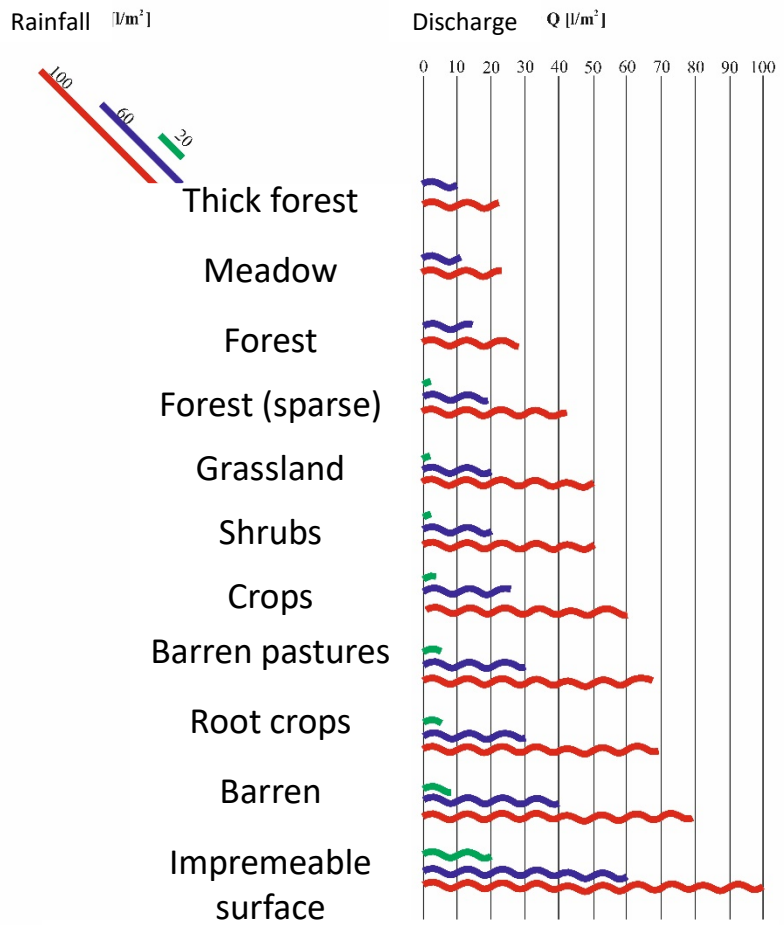


Source: Löschner L., Seher W., Nordbeck R., Kopf M. (2019) Blauzone Rheintal: A Regional Planning Instrument for Future-Oriented Flood Management in a Dynamic Risk Environment. In: Hartmann T., Slavíková L., McCarthy S. (eds) Nature-Based Flood Risk Management on Private Land. Springer, Cham. https://doi.org/10.1007/978-3-030-23842-1_15



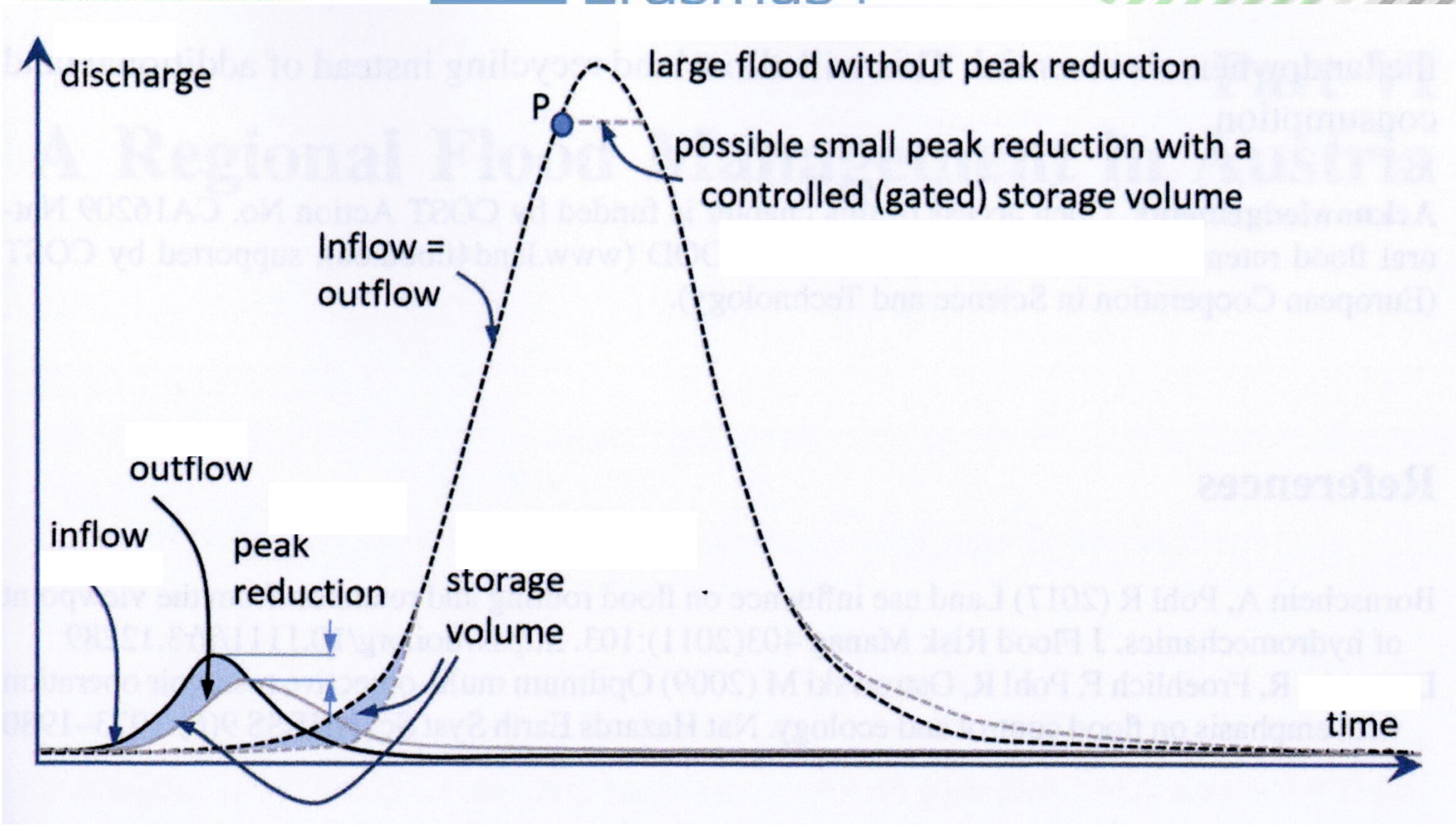
Ways to slow down the outflow and increase water retention in the catchment area: 1. forest roads, 2. the area intended for flooding, 3. the catchers, 4. small storm tanks, 5. safe drainage of water, 6. ditches, 7. dry tank

Source: Łapuszek M., Witkowska H.2005



influence of various forms of land management on its retention capacity and the amount of runoff

(Bayerisches Landesamt für Wasserwitschaft, Spectrum Wasser !, Hochwasser 1998)



Influence of small retention on floods' duartion and size; Hartman et al. 2019

A waterbar on a forest road, the source zone of the Bystra stream
Photos by J. Giżejewski

Rycerski Stream valley, flood terrace covered with vegetation that inhibits the flow of flood wave. Anti-rubble thresholds

The valley of the Rycerski river with a floodplain terrace covered with vegetation
Photo J. Giżejewski

System of anti-rubble thresholds and road protection at the Żabniczanka river
Photo J. Giżejewski

Odyssey
Oxford Debates for Youths in Science Education

Erasmus+

Legend: +++ significant impact, ++ moderate impact, + minor impact, +/- negative impact or no effect

Impact of selected small retention measures on water resources and the environment

Measure	Impact on						Threats
	surface water	retention in soil	ground-water	land-scape	biodi-versity	water quality	
Afforestation of agricultural land	+	+/-	+/-	+++	+++	++	reduced groundwater supply
Mid-field afforestation (reducing wind erosion)	+	++	+	+++	-/+	+	introduction of alien species
Agrotechnical solutions (improvement of soil structure)	++	+++	++	+	+	++	over-intensification of agriculture
Agrotechnical solutions - collecting water on farmland (small ditches, low dykes at the edge of the fields)	+++	+++	+++	+/-	++	+++	reducing the frequency of spring floods
Buffer zones along watercourses and reservoirs	+	+	+	++	++	+++	reducing the area of grasslands and arable fields
Controlled outflow from drainage systems	+	++	+++	+	+	+++	the possibility of excessive soil moisture
Construction of micro-reservoirs in ditches	+++	++	++	++	+++	++	excessive humidity of arable fields
Infiltration tanks and ditches	+	+	+++	+	+	++	groundwater pollution
Dry reservoirs / polders (river valleys used for agricultural purposes)	+++	++	+	+	++	+	periodic destruction of crops, excessive humidity / overdrying

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Impact of selected small retention measures on water resources and the environment

Measure	Impact on						Threats
	surface water	retention in soil	ground-water	land-scape	biodi-versity	water quality	
Restoration of meanders, construction of dug reservoirs in the river valley (water retention during high spring flows)	++	+	++	++	++	+	loss of agricultural land
Construction of reservoirs at the outflow of drainage systems	++	+	+	++	++	+++	loss of agricultural land
Construction of small (damming) reservoirs on rivers	+++	++	++	+	++	++	destruction of valuable ecosystems, problems with fish migration
Tanks dug in local depressions	+	++	+	+	++	+	destruction of valuable ecosystems
Rebuilding small ponds	++	++	+	++	+++	+++	changing the ecosystem to a less valuable one
Renaturization of rivers (restoring meanders)	+++	++	+	+++	+++	++	flooding agricultural areas
Restoration of wetlands and peat bogs	+++	+++	++	+++	+++	++	excessive limitation of the supply of water courses
Anti-erosion treatments (various)	++	+	++	++	++	++	changes in ecosystems

Odyssey
Oxford Debates for Youths in Science Education

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Thank you for attention

If you have questions,

you may contact us:

edukacja@igf.edu.pl

gozdzik@igf.edu.pl

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„Flood management of mountain catchments”

Material for teachers

With methodological guidelines, a lesson plan and an answer key to worksheets

The educational package "Flood management of mountain catchment" was developed within "Oxford debates for the education of young people in the field of mathematics and science" project.
It is a key material, facilitating the achievement of primary project goals, including increasing reasoning skills and interest in STEM, which in the future may result in taking up a scientific career.
When preparing students for the debate, one should not neglect the development of such skills as: communication excellence, argumentation or public speaking. Students should improve their ability to persuade effectively, argue properly, reason accordingly and speak out correctly. Composition of texts, using rhetorical means in oral statements, speaking in accordance with the rules of language culture, text interpretation, public speaking and presentation of texts, discussions and negotiations are of equally high importance.
In order to achieve the abovementioned goals, the implementation of thematic educational packages should be preceded by classes dedicated to preparation for debating as such. This can be accomplished in consultation with teachers of other subjects and the class teacher. The development of basic communication skills can be included in the class teacher's work plan, and the prepared lesson plans can be used during regular classes. Auxiliary materials can be found in the following documents:

1. **Warm up practice** – Annex No 2 to National frameworks for implementation of Oxford debates in STEM in school practice (pages 37-39);
   This document includes the following exercises: active listening, public speaking and debating skills.

2. **Lesson plans aimed at general development of debating skills** – Annex No 2 do National frameworks for implementation of Oxford debates in STEM in school practice (pages 40-55).

   This material consists of 7 lesson plans prepared by Dr. Foteini Englezou, president of the Hellenic Institute for Rhetorical and Communication Research. Scenarios are a guide to work. It is not necessary to follow all the lessons. The teacher can decide which scenarios (or their selected fragments) are most useful for working with a specific group of students. The document offers the following lesson plans:

   1. Communication skills
   2. Express your scientific argument, not your opinion
   3. Build a valid scientific argument
   4. Searching for evidence
   5. Enhancing students’ linguistic skills
   6. Rebuttal and refutation
   7. Fallacies

3. Methodological Guide for Teachers. ODYSSEY: Oxford Debates for Youths in Science Education

The final stage of preparation for debates based on specific packages is to familiarize students with the principles of debating, described in detail in the abovementioned document.

Flood management of mountain catchments

The "Flood management of mountain catchments" educational package consists of the following elements:

- Multimedia presentation;
- Video based on the presentation - https://youtu.be/17x-20l6rYo;
- Educational package "Flood management of mountain catchments" - material for students;
- Worksheets (the same for all packages);
- "Flood management of mountain catchments" - material for the teachers (with answer key).

It is recommended to implement the package during a minimum of three lesson units.

The "Flood management" package contains a set of materials to prepare and conduct a debate in which students will consider the advantages and disadvantages of nature-based measures for flood protection of mountain river catchments versus the construction of a large reservoir. Students will learn about the advantages and disadvantages of managing the mountain river catchment using natural methods and hydrotechnical solutions, such as building a large storage reservoir. The materials focus on the possible environmental consequences in terms of flood risk.

The package has been prepared to minimize the time needed to search for and select source materials. Students will receive ready-made materials in the form of source texts, tables, charts, described authentic stories, as well as auxiliary questions. On their basis, they develop arguments that can be used in the debate both to support the main thesis and to negate it.

The materials in the described package are intended for students of secondary schools. They can be carried out both during geography lessons, as well as during additional classes on science. Part of the work, consisting in the analysis of materials, preparation and appropriate qualification of arguments, can also be done as homework. Teachers may also consider organisation of a debate in grades 7-8 of primary school. However, it requires proper preparation of students, explaining more difficult terms appearing in the materials.

Lesson 1. How to protect from flooding?

In the first lesson, students should organize their knowledge about floods and its causes, as well as learn how to protect against floods, both through the nature-based measures, as well as through the construction of a retention reservoir. The pros and cons of both are described in the material for students. During the lesson, the teacher can also use the multimedia presentation prepared by Dr. Jerzy Giżejewski or watch a short movie (presentation with author's comment). The package also includes additional story cards describing how the Żywiec Catchment has changed after the construction of the dam in Tresna and the creation of the Żywiec Reservoir, and how silting of the retention reservoir occurs, on the example of the Żywiec Reservoir. The material for students also

include additional exercises, the performance of which will help students gather arguments in the discussion.

It is recommended that students receive the materials a few days prior to the lesson. This will allow them to get acquainted with the topic of the lesson initially and facilitate active participation in the classroom. A multimedia presentation or a video recorded by the author of the package can be used during the lesson. An open discussion of selected (previously assigned to students) geoengineering techniques is also beneficial.

Lesson 2. „Small retention measures for flood protection of mountain river catchments are more effective than construction of a large dam reservoir" – constructing arguments for and against the resolution

The aim of the second lesson is to formulate as many arguments as possible (both for and against the resolution) that will be used by students during the debate, summarizing the work with the package.

Lesson plan

1. Organizational issues, checking the attendance list, familiarizing with the topic and objectives of the lesson [5 minutes].
2. Preparation of arguments [25 minutes]

The teacher divides the class into teams of two. Each team receives 16 **question cards** available in the educational package (material for students) and 2 copies of worksheet No. 1 (one for each student individually). Based on the questions, students formulate arguments for the presented resolution, against the resolution and those that are debatable and can be used in the discussion by both teams. Students work together, but each student individually completes his/her worksheet. There are examples of selected arguments for worksheet 1 presented in the answer key in this material.

3. Teams: proposition and opposition are formed [10 minutes].

Team selection may be executed in many ways, each of them having both advantages and disadvantages.

- Students declare which arguments are closer to their beliefs. The teacher divides the class into teams (each with a similar number of students) in the manner reflecting their convictions.
- The second method assumes a division similar to the one above, with the difference that ultimately the team consisting of the supporters of a given resolution becomes the "opposition" team, while the opponents of the thesis become "proposition" team. The supporters of such a division assume that it teaches the participants of the debate to a greater extent to use arguments supported by facts, and is less based on emotions.
- Alternatively, division into teams can also be done randomly.
- Finally, team selection can also be made by the teacher in a subjective way, ensuring that each team has both leaders and students who require more help, so that both teams have similar "winning potential". In order to save time for division, the teacher can do it at the beginning

of the lesson, for example by distributing worksheets printed on sheets of different colours or marked in some other manner.

4. The teacher distributes worksheets number 2 to the students (one for each student) and explains the homework. An example of a filled out worksheet is available in the answer key in this document.
5. Students in each team read prepared arguments in accordance with the assignment to a given group. Each student receives 1 argument, which he/she will develop (as homework) according to the guidelines in worksheet No. 2.
6. Each team also appoints 3 people who will present the arguments prepared by the entire group. Students decide the order of their speeches. During the debate, other team members who are not directly involved in the debate, fill out worksheet No. 3
7. Summary of the lesson, evaluation of students' work [5 minutes].

Lesson 3. Debate

During the final lesson, the teams conduct a debate according to the guidelines contained in the "Methodological Guide ..." It takes 45 minutes in total to conduct a full debate. During the debate, the teacher does not comment on the arguments or indicate the fallacies made by the students on an ongoing basis.

An exercise-based debate should be structured as follows:

1. Opening of the debate by the moderator/chairperson [3 minutes].
2. Initial vote by the audience [2 minutes].
3. 1st Researcher-Debater of the A research-team: Constructive Speech [4 minutes].
4. 1st Researcher-Debater of the B research-team: Constructive Speech [4 minutes].
5. Cross-fire between the researchers-debaters (1) of both research teams [3 minutes].
6. 2nd Researcher-Debater of the A research-team: Rebuttal Speech [4 minutes].
7. 2nd Researcher-Debater of the B research-team: Rebuttal Speech [4 minutes]
8. Cross-fire between the researchers-debaters (2) of both research teams [3 minutes].
9. Preparation time for the Summary and Final Rebuttal by both research teams [2 minutes].
10. 3rd Researcher-Debater of the A research-team: Summary Rebuttal [2 minutes].
11. 3rd Researcher-Debater of the B research-team: Summary Rebuttal [2 minutes].
12. Grand Cross-fire between the researchers-debaters (1 & 2) of both research-teams [3 minutes].
13. 3rd Researcher-Debater of the A research-team: Final Focus Rebuttal [2 minutes].
14. 3rd Researcher-Debater of the B research-team: Final Focus Rebuttal [2 minutes].
15. Final vote by the audience / Short written feedback [3 minutes].
16. Presentation of the results by the moderator [2 minutes].

If the debate takes place during extra-curricular activities, then it is recommended to devote, for example, 90 minutes for this part. This will allow you to prepare the room for the debate, recall the rules, conduct the debate and discuss its course and finally evaluate the work of students.

In terms of classroom conditions, it would be ideal to allocate two adjoining lesson units to the debate. Taking into account the school circumstances, organizational difficulties and the inability to devote too many lessons to content extending the core curriculum, the debate can be conducted in one lesson, while maintaining high discipline in time. In this case, it is recommended that during the next lesson with the class additional 10 minutes are spent discussing the debate, pointing to strengths and mistakes made by the participants of the debate.

In this format, 6 students (3 from each team) actively participate in the debate. The teacher may also appoint a moderator from among the students and a time keeper. The rest of the students will receive worksheet number 3. Their task will be to listen carefully to the debate and to note the opposing team's strengths and areas for improvement, and to justify their choice. Completed worksheet no. 3 may be the basis for issuing a grade for activity in the lesson for students who did not take part in the debate directly, but participated in its preparation and were active observers of its course.

Worksheet No 1 – answers

The table below contains examples of answers to question cards gathered in the worksheet No. 1. The answers may help to formulate arguments in the debate on the presented resolution.

FOR	„GREY AREA"	AGAINST
Question card 1. *What is the impact of small retention measures on the size of surface runoff?* Small retention measures significantly reduce surface runoff. Some of the measures (e.g. field terracing) are a long-term activities, requiring consistency of actions. *Question card 4.* *Why is it important that afforestation corresponds to natural habitats typical for particular place (in terms of climate and altitude)?* Afforestation corresponding to natural habitats in mountain areas (in Poland: mixed fir and beech forest with thick level of undergrowth) is a proper way of land use in terms of reducing the surface runoff. It helps to keep water in a catchment for longer period. Currently, in Poland it is additionally supported by payments from EU funds. *Question card 8.* *What is the impact on rainfall runoff and retention in case of a change in land use from agriculture to tourist services?*	*Question card 2.* *What difficulties can arise when planning small retention measures on private land? How can you deal with it?* Implementation of small retention measures on private land requires extensive awareness raising and good will of the interested parties themselves, which reduces the range of this type of intervention. *Question card 5.* *Field terracing consolidates networks of field roads. How does it affect the surface runoff?* Field terracing consolidates networks of field roads and facilitates their transformation into runoff routes. *Question card 7.* *Do the costs incurred for small retention measures (e.g. afforestation) end after these works have been completed?* Afforestation requires not only its implementation, but also subsequent care - protection against damage caused by animals, fire protection, sanitary	*Question card 3.* *What is the effectiveness of small retention measures during very heavy rainfall or rapidly melting snow?* Small retention measures do not protect against a rapid increase in surface runoff in cases of strong precipitation (large and/or long-term) and rapidly melting snow. *Question card 6.* *Terracing requires heavy vehicles, which enter the filed. How do they affect the ground retention?* Field terracing requires preparation of network of roads, which enable access of heavy machines and vehicles. Networks of access roads, which serve as runoff channels, reduces the positive effect of field terracing on the increase of ground retention (reduced inclination, facilitated plowing on the same level). *Question card 9.* *Does afforestation have only positive consequences? May farmers have claims for these actions?*

The transition from extensive agriculture to recreation and tourist management (agrotourism) is now a common phenomenon (especially in areas located on the slopes of valleys). Administrative support should facilitate changes and extend them to the afforestation of wasteland. *Question card 13.* *How do anti-rubble dams constructed in the upper parts of rivers affect the transport of sediments and the flood risk?* Hydro-technical solutions constructed on the upper part of streams in the form of anti-rubble dams reduce bottom erosion, transport of sediment, reduce the flow velocity, and decrease the flood wave height. Each built dam fulfills this role. Therefore, their construction can be carried out as far as possible - of course, the effects are proportional to these possibilities.	cuts. Therefore, broad and persistent awareness raising is necessary, which is not always effective. *Question card 10.* *What is the impact of demographic change on the effectiveness of small retention measures? Does the transition from extensive economy to agritourism have only positive effects? How aging of farmers affects land use?* The abandonment of farming (extensive - for own needs) results from the aging of the population of inhabitants of farms scattered on the slopes. The process may lead to the creation of wasteland *Question card 12.* *Does the construction of anti-rubble dams in upper parts of rivers cause other effects (lateral erosion, increase in the amount of sediment and debris) that reduce the positive effects of such activities?* Construction of anti-rubble dams increases lateral erosion below each dam (widening of the riverbed), which results in increased sediment delivery to the riverbed, which can force large changes in the lower part of a stream. Widening of the riverbed increases its capacity and reduces the water levels.	Afforestation requires separation of afforested areas and areas used as breeding areas, which is a conflict of current (breeding) and long-term (forest management) interests. An additional issue is that flood protection measures (especially in case of applying nature-based solutions) are often applied in upper parts of catchments, whereas their effects are expected in lower parts, so in remote areas (social interest). *Question card 11.* *How can adaptation of farms and local roads to the needs of agritourism change the water regimes of rural areas?* The development of the network of agritouristic places and recreational services causes the expansion of the network of paved access roads and areas with a high surface runoff rate (areas of cut lawns, playgrounds, parking lots). This type of land use change can have a negative impact on the retention properties of peripheral rural areas. *Question card 14.* *Do hydro-technical solutions become old? Does their effectiveness change over time?* Construction of anti-rubble dams affects the conditions of flow and sediment transport shortly after construction - until the holes near the dams are filled in with sediment, which can take place even in one flood episode. Later, the effect of the dams is limited to the dissipation of flow energy.

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Worksheet No 2 – examples of arguments

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals
(Claim) Small retention measures in the upper sections of the streams, e.g. in the form of rock debris and traps, are an effective method of protection against flooding. (Warrant) The construction of debris thresholds and sediment traps reduces the intensity of abrasion, and also limits sediment transport downstream. (Evidence) This reduces the slope and increases the dissipation of the flow energy, which, according to the principles of hydrodynamics, leads to a reduction of the flood wave (the flood wave is lower, but lasts longer). (Impact) Any actions causing decrease of the height of flood wave reaching built-up areas (even if the high water level will last longer) increases the chance of keeping the flowing water in the riverbed and reduces the risk of flooding and destroying infrastructure e.g. buildings.	Small retention measures require significant budget, whereas they do not provide full flood protection. Full flood protection is provided only by the construction of dam reservoirs with a capacity exceeding 0.6 of the annual runoff from the catchment area above the planned reservoir.	Small retention measures are mainly made of local materials, it can be carried out gradually, the costs are lower than in other types of constructions and the gradual development of measures allows to adjust the expenses to the financial conditions.
		The costs of building a large dam reservoir can exceed many times the losses from even catastrophic flood. Social costs can also be very high - the need to relocate households and exclude some area from agriculture.
	Debris thresholds and sediment traps work for a limited period of time until the space above them is filled, then their impact is significantly reduced.	The construction of anti-debris thresholds, in addition to reducing abrasion and sediment transport in the initial period of operation, causes expansion of riverbed above the thresholds and the formation of wetlands with rich vegetation, which also increases the retention and reduces the velocity of the flood wave.
		Anti-rubble thresholds – even filled with sediment -reduce slope and increase flow energy dissipation. When planning the small retention measures, it is necessary to ensure that only those technical measures are taken, which cause desired environmental changes.

Argument with reasoning	Predicted rebuttals of opposite team	Answers to rebuttals
(Claim) The only effective measure to protect the lower parts of the catchment area against the effects of flooding is the construction of a large dam reservoir. (Warrant) The large reservoir has such capacity that may contain the total amount of water drained from the upper part of the catchment during a flood. (Evidence) Full flood protection is provided by the construction of dam reservoirs with a capacity exceeding 0.6 of the annual outflow from the catchment area above the planned reservoir. (Impact) Accumulation of total surplus of rainwater in the retention reservoir ensures full protection of the areas below the reservoir against flooding.	The construction of large retention reservoirs (dam reservoirs) is possible only in areas with an appropriate land relief. Vast, deep valleys with natural narrowings of river bed are necessary, in which the construction of a dam of relatively small dimensions compared to the reservoir area can be planned.	The places that meet the indicated construction conditions should be used, and in the absence of these, smaller reservoirs should be built so that their total capacity corresponds to e.g. 100 year flood discharge.
		Such small reservoirs could be empty, and their bottoms could be managed in a seasonal way - without permanent buildings, eg for wicker plantations as a source of fuel biomass.
	Areas designated for flooding should be without infrastructure. Otherwise, construction entails enormous costs of relocating industrial and residential infrastructure outside the foreseen reservoir's area, and resettling people. In the case of the construction of the Żywiec reservoir, which, despite favorable morphological conditions, does not provide protection for the Oświęcim Basin and the Upper Vistula Valley against 50 or more years flood discharge, it required the relocation of three towns and the resettlement of 3 800 people. And in the last 20 years, two floods have reached the 100 year flood discharge.	Retention reservoirs are built not only for flood protection. Even if this is the main purpose, such reservoirs also have a recreational function. They can also provide utility water for the inhabitants of nearby towns. Water retention is of particular importance in a country with so little freshwater resources.
		The construction of a dam reservoir may also be accompanied by the construction of a hydropower plant. Profits from electricity production will lower the cost of maintaining the reservoir. It will also contribute to increasing the share of renewable energy in the country's energy balance.

Worksheet no. 1

The educational package contains a set of questions to help prepare arguments for discussion on the resolution. On their basis, prepare a set of arguments and group them into those that are clearly in favor of the resolution, against the thesis, and those arguments that can be used by both teams. Write them down in the appropriate parts of the table.

FOR	„GREY AREA”	AGAINST

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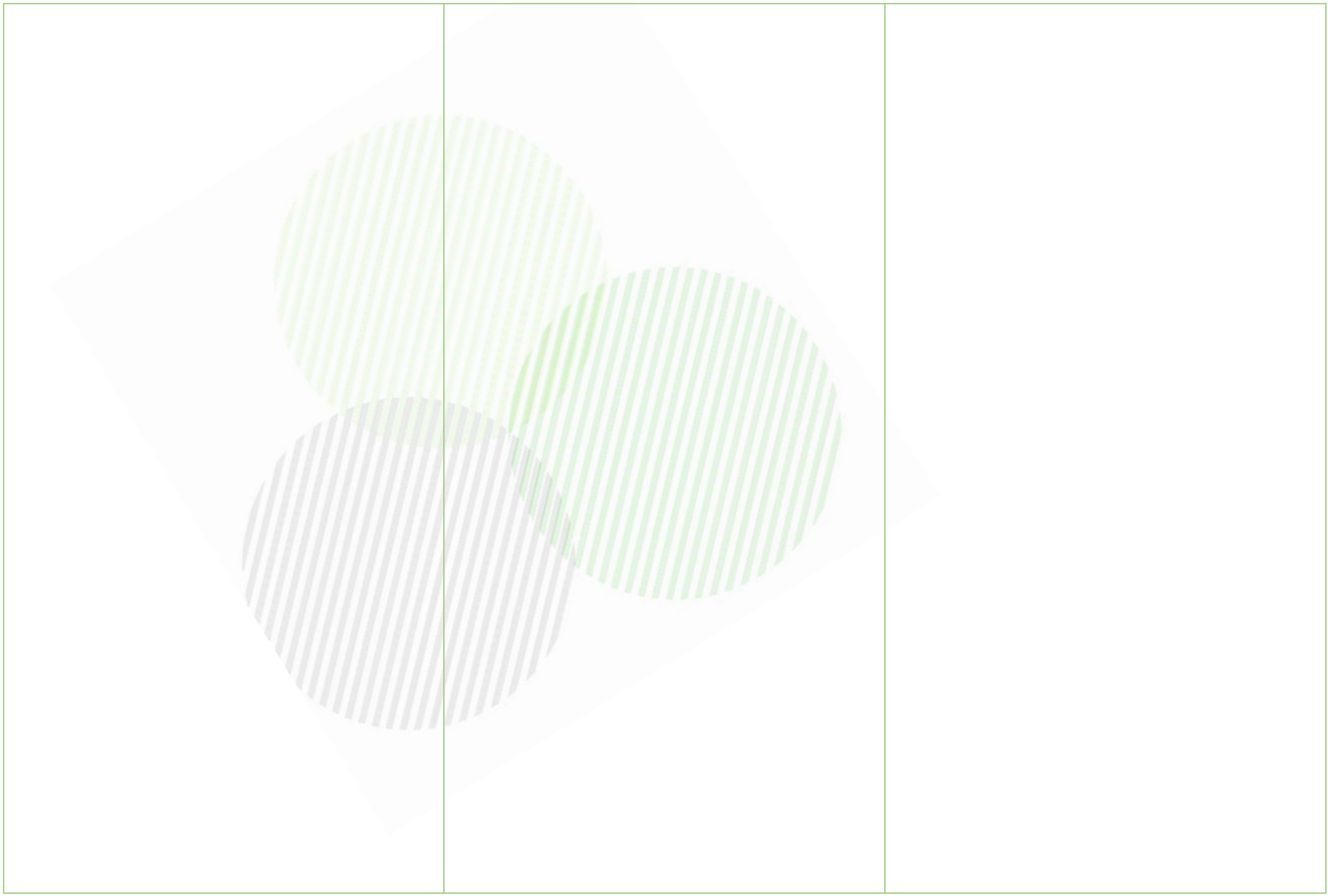

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Worksheet no. 2

Based on the materials provided by the teacher, prepare arguments for discussion. One group of students prepares arguments supporting the resolution, the other one - opposing arguments. Use the proposed template.

ARGUMENT 1.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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ARGUMENT 2.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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Worksheet no. 3

Name and surname:……. Class……. Team: proposition/opposition

During the debate, hear and observe carefully the speeches of the debates from the other team. Then, evaluate which speech convinced you the most and which areas of your opponents' speech should be improved.

1. In terms of **argumentation (**e.g. the quality of the arguments presented, credibility of the data and scientific evidence) in the rival team I was most convinced by the speaker No. .....

Reason:

……

……

……

……

……

2. In terms of **the style of presentation and communication with the audience** (e.g. confident, persuasive, authentic and dynamic posture, moderate gestures, assertive voice variety, good eye contact with the audience, use of moderate humor, friendly and professional approach to all participants, effective use of body language) in the rival team I was most convinced by the speaker No. .....

Reason:

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Indicate the element of the rival team's performance that requires improvement. Justify your answer.

……

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Reason:

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