ITP

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IUNG Instytut Uprawy Nawożenia i Gleboznawstwa

Poland – nutrient balances as a tool for sustainable nutrient management

Ministry of Agriculture and Rural Development
Institute of Soil Science and Plant Cultivation – State Research Institute
Institute of Technology and Life Sciences
| Poland

28-29 April 2015, Oldenburg, Germany

– HELCOM Workshop on status of nutrient bookkeeping

Structure

- Introduction: Polish agriculture at glance – extensive production at the UE level
- Policies and actions effectiveness - constantly decreasing impact on water quality
- Nutrient balances – new tools and new ideas



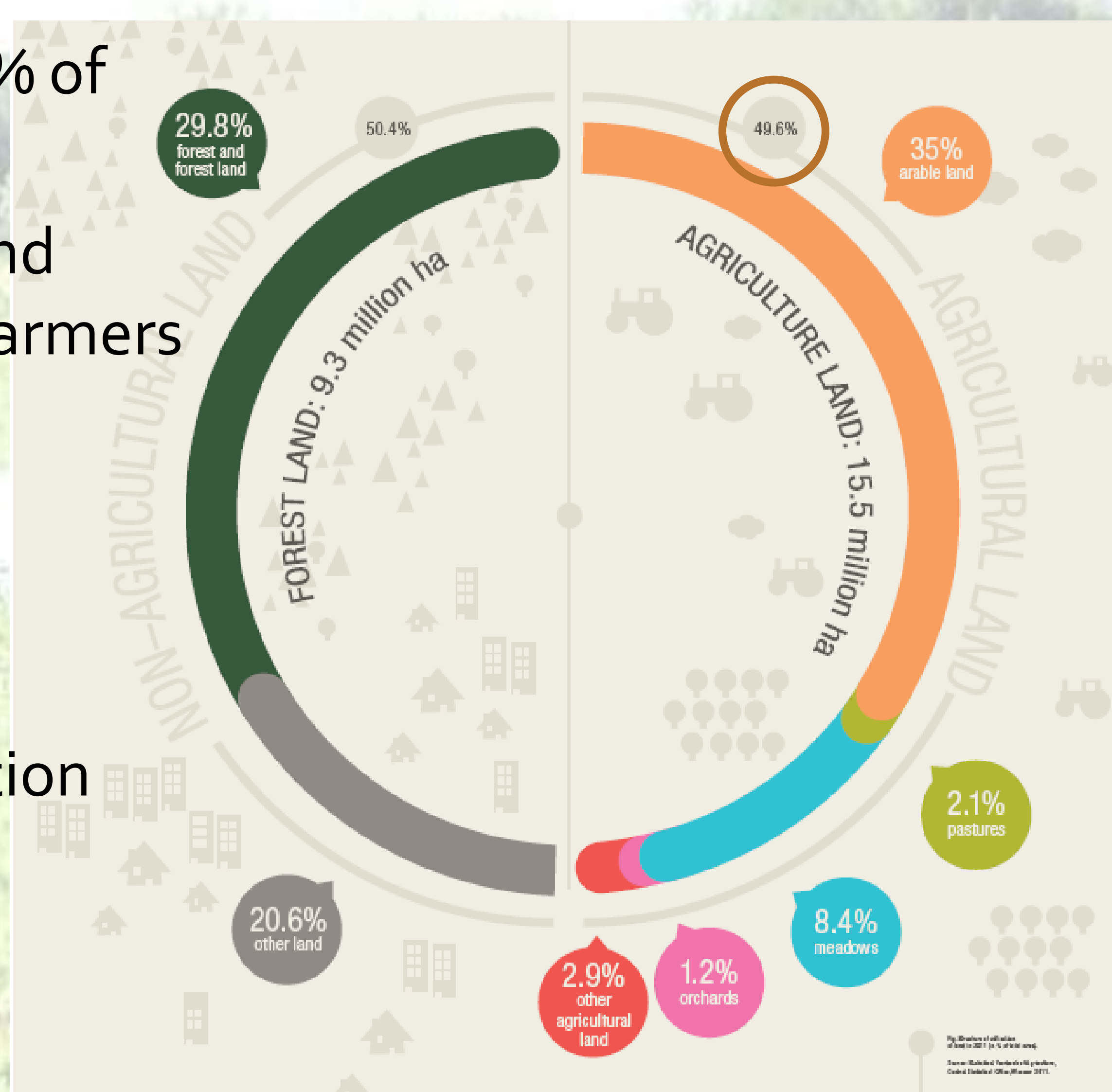
Photos: Katarzyna Kowalczewska, Wanda Klepacka, MRiRW, Jacek Walczak, IZOO PIB

Polish Agriculture

Photos: Anna Nieróbca, IUNG PIB

Key facts about Polish agriculture

- Agricultural land 49,6% of total country area
- 88% of agricultural land utilized by individual farmers
- 2nd in the EU-27 (after Romania) in terms of number of agricultural holdings
- Nearly 40% of population live in rural areas (14,9 million)



Source: Central Statistical Office 2011

Biophysical conditions in Poland

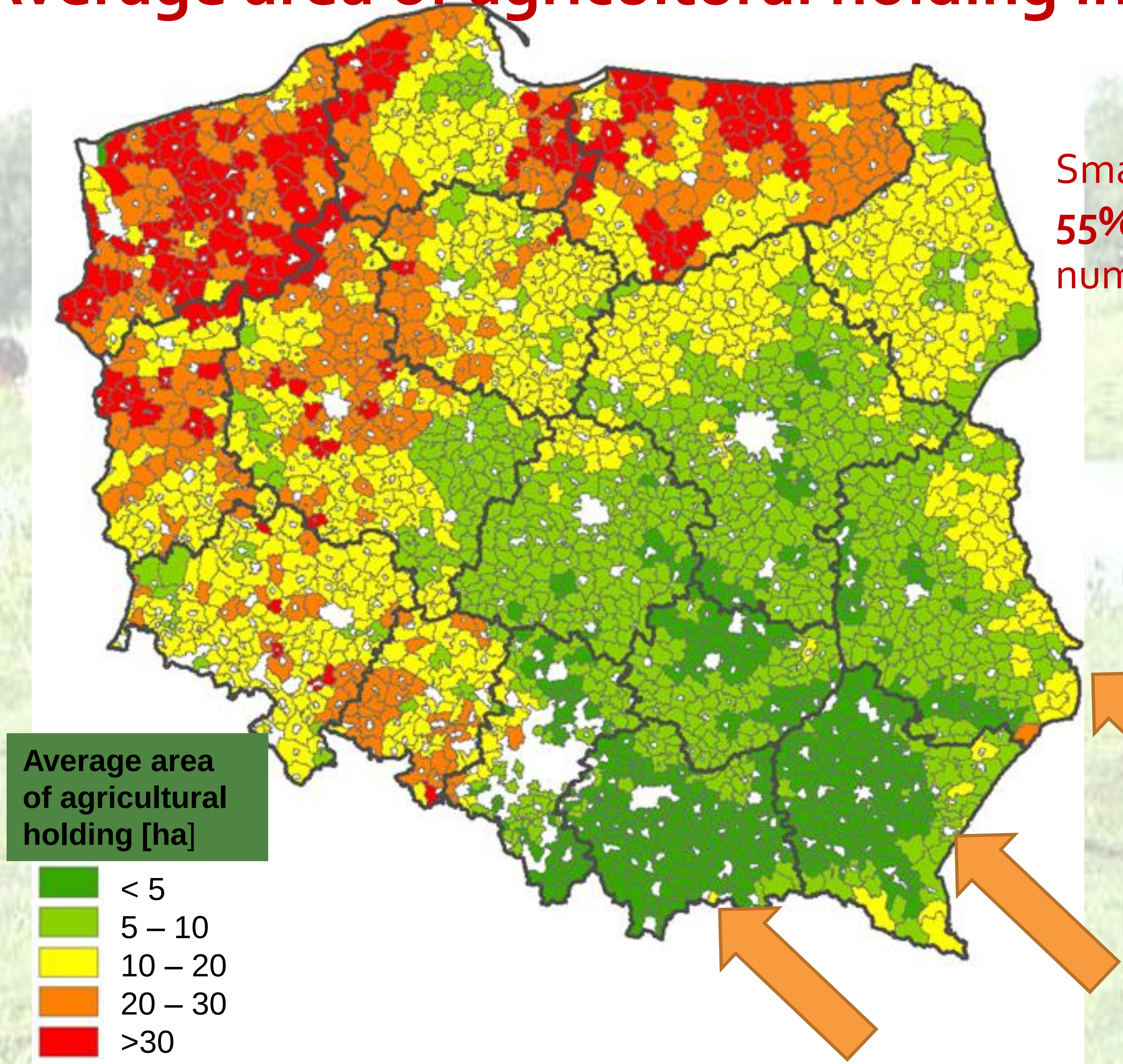
Large share of soils of limited suitability

- 30% of very acidic soils
- 60% of sandy soils

Productivity potential is greatly reduced by climate conditions

- limited precipitation (average 550 mm/year)
- relatively short vegetation season (200-230 days/year)
- seasonal drought condition (last 20 years – 5 drought years)

Average area of agricultural holding in Poland

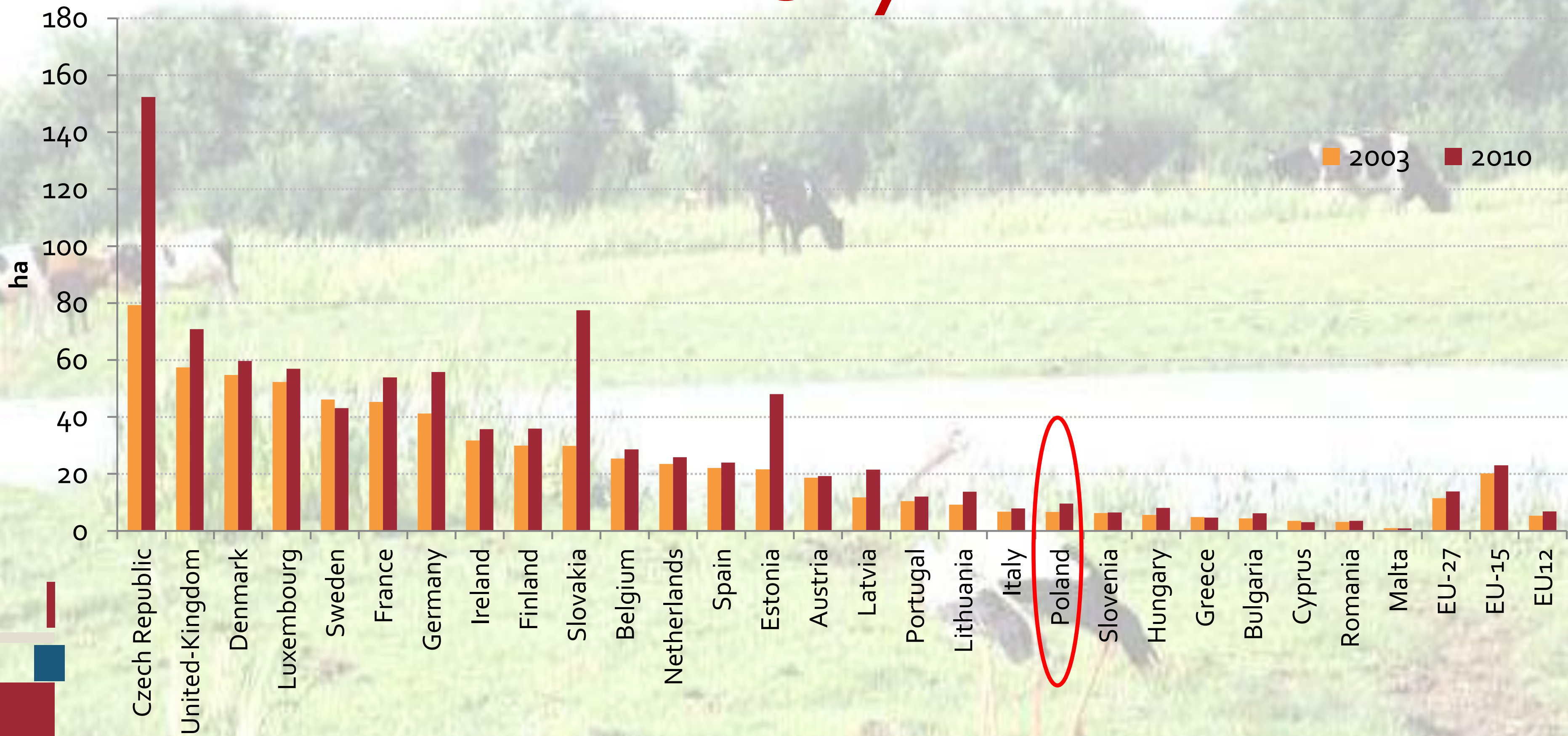


Small farms (1 - 5 ha) **55%** of the total number of farms

The area of holdings raises from south east to north west

Source: IUNG PIB

Average area of agricultural holding in EU 27



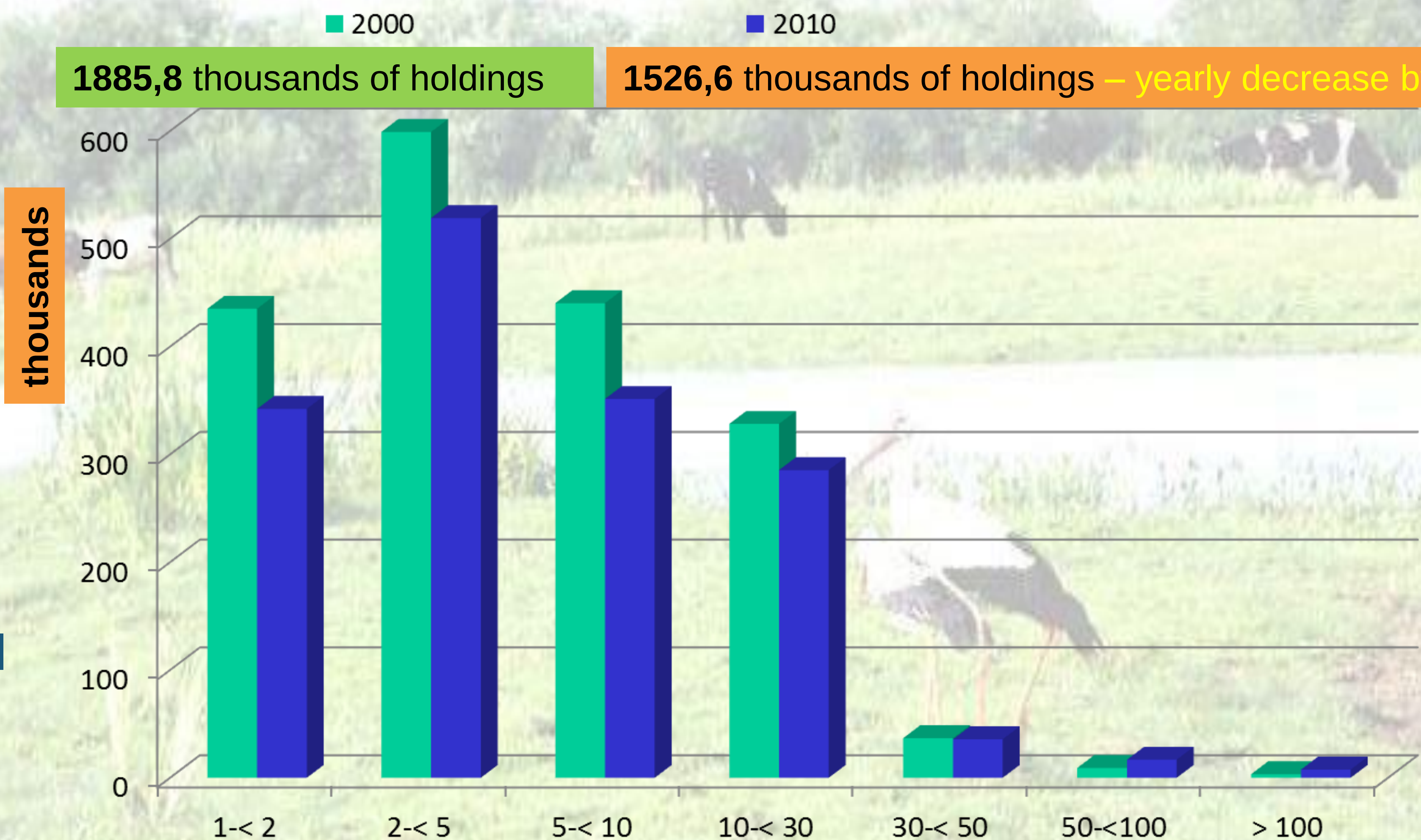
The average size of farm **in the <u>north</u> of Poland is ca<u>. 18 ha</u>**, whereas in the **<u>south</u> it is less than <u>4</u>**

Source: Central Statistical Office 2013

Changes in the number of agricultural holdings*

1885,8 thousands of holdings

1526,6 thousands of holdings – yearly decrease by 1,4 %

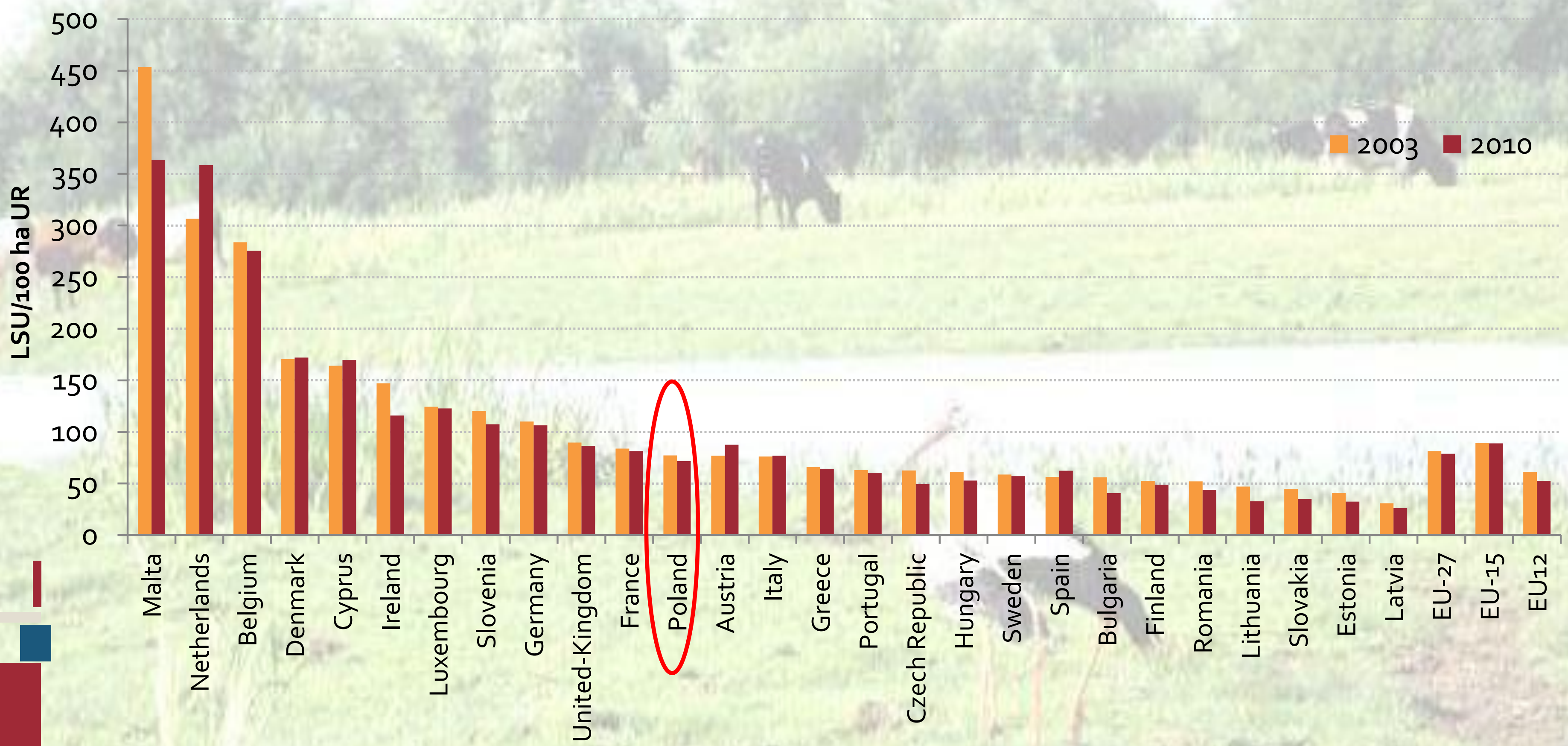


Groups of holdings (ha)

***   Refers to holdings above 1 ha***

Source: dr Jerzy Kopiński, IUNG PIB: Summary meeting on the IUNG's research programme 2014, and Central Statistical Office.

Number of livestock units (LU) per 100 ha in EU 27



Source: Central Statistical Office 2013

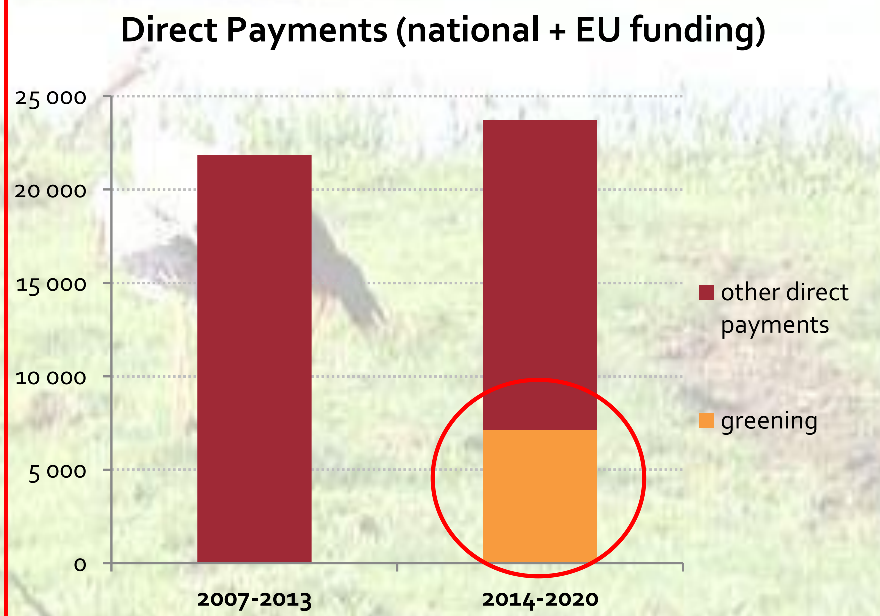
Agri policies and actions effectiveness

Mainstreaming of water actions into agri policies and actions - NOW

National level

- National strategy for sustainable development of rural areas, agriculture and fishery 2012-2020
- Direct Payments
  (c.a. 14 mils. of ha = 90% agri land)
- Rural Development Programme
  (Shifts towards more greener and targeted measures)

Common Agriculture Policy



Relevant legislation

- National Act on Fertilizers and Fertilizing – mandatory schemes
- Nitrate Directive – Nitrate Vulnerable Zones – mandatory schemes
- Act on Rural Development for RDP 2014-2020 – voluntary schemes
- Cross compliance – mandatory schemes

New RDP measures reducing nutrient load in waters

- New AEM contribute to the reduction of N and P directly:
  - Package 2 Soil and water protection - appropriate agronomic practices (including intercrops , rational fertilization based on fertilizer plan);
  - Package 1 Sustainable Agriculture;
  - Packages 4 and 5 - Valuable habitats and endangered species of birds in Natura 2000 sites, valuable habitats outside Natura rational management of minerals and reduce their losses.
- Investment on NVZ – manure tank construction and precision fertilizing equipment

Controlling systems / responsible authorities

- Control
  - The Law on Environmental Inspection/ Water Law
  - Act on Fertilizing and Fertilizers
  - Action Programmes Nitrate Directive
- Responsible authorities

WFD environmental goals

- TN and TP concentrations limits in rivers – vital for the reduction of discharges of N and P - they should be the starting point for all planning work in water management and water protection within the Member States , including the Baltic Sea countries

WFD: environmental goals for P

- Benchmarks for very good ecological status: the value of P tot .(TP) in the case of a large lowland river (Type 21) should be of 0.20 mg P dm^3, in the case of river estuaries under the influence of saline water (Type 22) - 0.17 mg P dm^3

- TP concentration limit for GES, ie corresponding to the environmental goal should be **0.3 mg P dm^3** (type 21) and **0.31 mg P dm^3** (type 22) according to the WFD requirements this concentration is satisfacotry

- TP concentrations observed in 2013 were 0.15 mg P dm^3 in the Vistula river and 0.2 mg P dm^3 in the Oder river (data from the lowest points of monitoring on these rivers - type 21).Thus, the GES in relation to the concentration of TP in the waters of the Vistula and the Oder is already met.

WFD: environmental goals for N

- TN concentration limit for GES which is equivalent to the environmental goal, the fulfillment of which applies to Poland, according to the results of the verification limits for classes TN ecological status should be respectively 4.0 mg dm^3 (for type 21) and 2.7 mg dm^3 (for type 22).
- TN concentration in 2013 – lowest located monitoring points amounted to **2.0 mg N dm^3** in the Vistula and **2.9 mg N dm^3** in the Oder River.
- Environmental goals in relation to the concentration of TN in the lowermost monitoring stations in waters of the Vistula and the Oder rivers (type 21) is therefore satisfying.

HELCOM

- TN
- Wisła Odra rz. Przymorza+inne (10%)
- 97 800 t + 57 694 t + 15 550 t = 171 044 t – 43 610 t (CART) = 127 098 t (ład. docelowy)
- CART = 43 610 t = 39 645 t (Wisła+Odra) + 3965 t (rz. Przymorza + inne)
- Wisła Odra
- 97 800 t + 57 694 t = 155 494 t – 39 645 (CART Wisła+Odra) = 115 553 t
- ⇓ ⇓
- 71 643 t 43 910 t
- Wisła (34 km3/rok) Odra (16.7 km3/rok)
- ⇓ ⇓

2.11 mgN/dm3 2.63 mgN/dm3

- TP
- Wisła Odra rz. Przymorza+inne (9%)
- 6 497 t + 4 092 t + 953 t = 11 542 t – 7 480 t (CART) = 4 062 t (ład. docelowy)
- CART = 7 480 t = 6 862 t (Wisła+Odra) + 618 t (rz. Przymorza + inne)
- Wisła Odra
- 6 497 t + 4 092 t = 10 589 t – 6 862 (CART Wisła+Odra) = 3 727 t
- ⇓ ⇓
- 2 311 t 1 416 t
- Wisła (34 km3/rok) Odra (16.7 km3/rok)
- ⇓ ⇓

0.07 mgP/dm3 0.08 mgP/dm3

HELCOM

- The question of the unusually large and unjustified Polish responsibility for the reduction of TN and TP loads among the Baltic Countires ?
- According to the CART reduction targets for TN (89 000 tonnes / year) , and TP (14 000 tonnes / year) it is expected that the annual load for TN, discharged from Polish area , will be reduced by 43 610 tonnes / year, and the annual for TP load by - 7 480 tonnes / year → this 50 % of the total reduction in nitrogen and phosphorus loads , whereas the percentage of Polish TN riverine export was in 2000 and 2006 - respectively 26 - 24 %, while the percentage of Polish TP riverine export - respectively 37-36 %

HELCOM

- How to justify HELCOM reduction targets implementation, if:
  - current monitoring data re. nitrates and phosphates indicate decrease in concentration in recent years
  - Water monitoring results for 2013 indicate that the environmental goals for the lowermost monitoring points in relation to the concentrations of phosphorus and nitrogen in the Vistula and the Odra rivers are already fulfilled.

Nutrient balances – new tools and new ideas

IT tools supporting sustainable nutrient management

Advisory system for fertilization on arable land:

- Calculation of fertilizer doses based on the nutrient balance at the **field scale**
- Recommnedations for NPKMg fertilization and soil liming

The assessment of the nutrient management practices in plant production at the **farm scale** based on soil surface nutrient balance

- Advisory system for fertilization at the **field scale**
- nutrient balance calculation at the **farm scale**
  (the compilation of NawSald and Macrobil)

MACROBIL – A Decision Support System for sustainable nutrient management at the farm level

The purpose of this tool is to assess of correctnesss of fertilization practice used at the farm based on the soil surface nutrient balance.

In soil surface balance all nutrients that enter the soil are treated as **inputs**. All nutrients removed from the soil constitute the **output**.

Inputs:

- fertilizers (NPK) applied
- manures
- another external sources of nutrients (organic fertilizers, soil improvers, etc.)
- by-products incorporated into the soil
- biological fixation of nitrogen (leguminous crops)
- atmospheric deposition of N

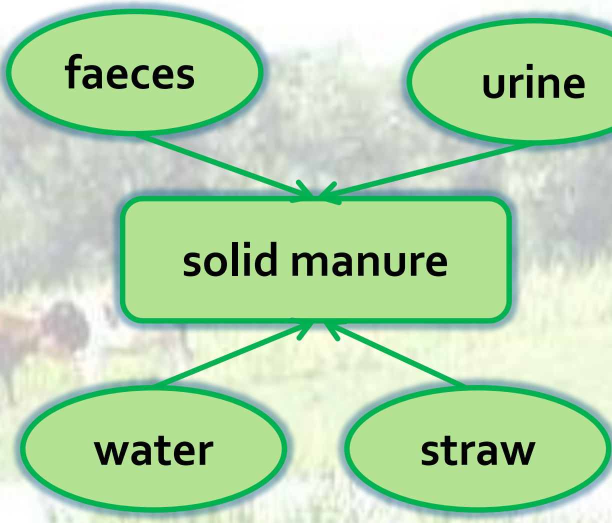
Output:

- nutrients removal in plant products

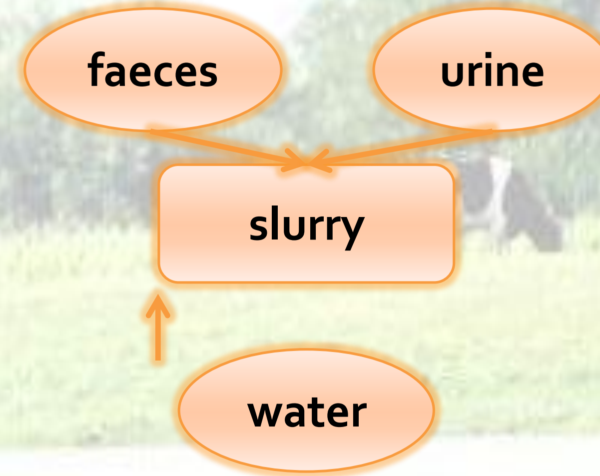
Submodels for estimation of some elements of nutrient balance

- Manure production
- Biological fixation
- Nutrients input in incorporated by-products
- Nutrients off-take

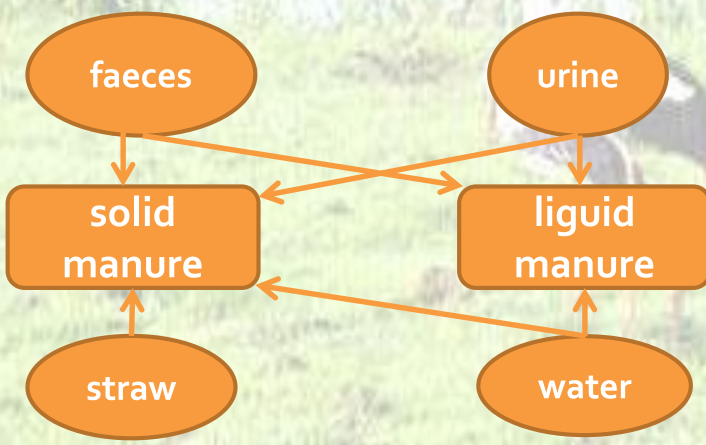
Manure production submodel



Deep litter barn



No litter barn



Shallow litter barn

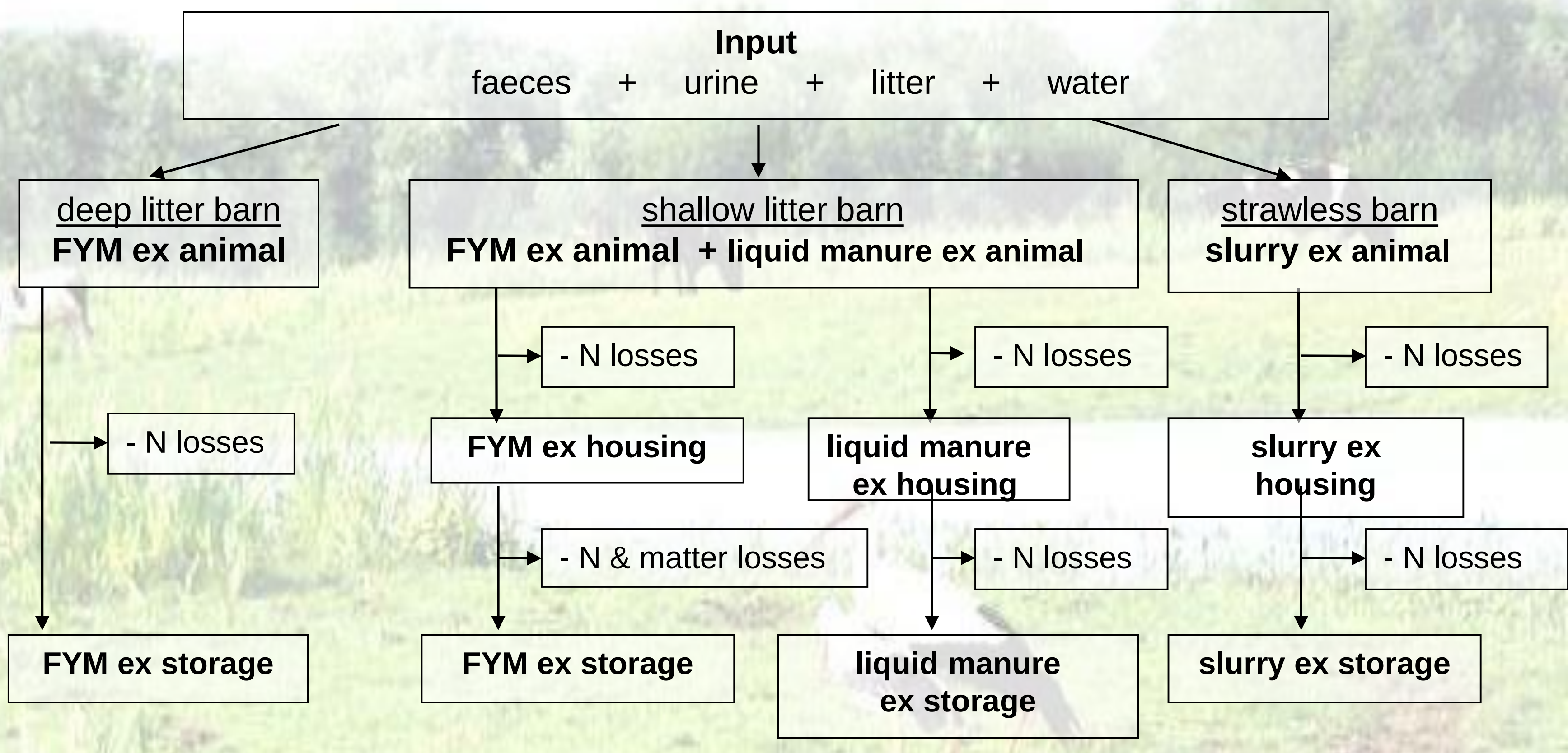
Manure production submodel

- Required data:
  - number of animals
  - animal housing system (no litter, shallow litter, deep litter)
  - grazing period

Manure production submodel

The amount of NPK in animal excreta (kg per animal unit per year)

Animal species	Faeces				Urine			
	Fresh matter	N	P	K	Fresh matter	N	P	K
Cattle	(Mg)				(Mg)			
Calves 0 - 3 months (0 - 90 kg)	0,79	2,36	1,86	1,2	0,84	5,82	0,006	3,757
Calves 3 - 6 months (90 - 185 kg)	1,68	5,04	3,94	2,34	1,78	12,24	0,014	7,99
Heifer 6 - 12 months (185 - 310 kg)	2,63	7,3	3,57	3,51	2,26	14,9	0,1	17,612
Beef 6 - 12 months (200-320kg)	2,52	8	4,05	4,33	2,31	14,8	0,08	14,722
Diary > 6000 ltr	12,8	51,9	29,70	21,92	6,16	67,4	0,46	61,88
Pigs								
Sows	1,116	4,6	2,4035	2,232	1,85	16,83	0,9775	4,2895
Fattening pigs 70 - 110 kg	0,82	4,44	2,76	2,664	1,64	11,352	1,173	3,864
Horses								
Small horses	1,75	8,37	2,76	6,624	0,64	10,674	1,55	14,072
Large horses	1,96	9,37	3,09	7,416	0,72	11,94	1,74	15,768
Sheep								
Rams foals	0,48	6,03	1,826	6,084	0,96	11,556	0,935	12,969
Sheep >12 months	0,38	3,6	1,1	3,699	0,76	7,002	0,561	7,866
Poultry								
Hens	0,062	0,684	0,162	0,274				
Broilers	0,031	0,468	0,0702	0,136				



N losses at stable and at storage are considered in submodel

The results of manure production symulation

Nutrient off-take submodel

Internal database: Standard NPK uptake per unite of yield

Crop	Main product			By-product			Total		
	N	P	K	N	P	K	N	P	K
Cereals									
Winter wheat	18,9	3,6	4,3	5,2	0,8	10,0	23,7	4,3	12,5
Spring wheat	21,0	3,8	4,6	5,5	0,8	10,7	25,1	4,5	13,5
Barley	16,3	3,5	4,8	5,5	1,0	12,0	21,0	4,2	13,6
Rye	15,7	3,4	4,8	5,5	0,9	11,8	21,6	4,4	17,9
Triticale	17,9	3,6	4,6	5,9	1,0	12,1	24,1	4,7	17,5
Maize	15,5	3,4	4,6	12,9	2,0	18,6	28,4	5,4	23,2
Mixtures	16,5	3,8	5,1	6,1	1,3	13,5	22,0	5,0	17,2
Legumes									
Beans	39,8	5,4	11,3	13,4	1,4	17,1	54,2	7,1	30,2
Pea	34,3	4,2	10,8	16,8	1,8	17,5	48,6	5,9	26,9
Lupine	55,0	7,0	12,8	12	1,6	15,3	67,0	8,6	28,2
Mixture cereals + legumes	25,4	4,0	7,9	11,4	1,5	15,5	35,3	5,4	22,0
Oil crops									
Rape	33,6	6,9	8,7	6,9	1,5	16,9	44,5	9,7	33,2
Flax	33,6	6,7	8,3	5,3	1,4	12,0	40,3	8,9	26,2
Sunflower	28,0	7,1	19,8	15	3,9	41,3	55,0	14,2	94,2

Nutrient off-take = yield * standard NPK uptake

Biological N fixation

Coefficient of biological N fixation by legumes

Crop species	N biologically fixed (fraction of total N uptake)
Faba Bean	0,85
Pea	0,85
Lupine	1
Soya bean	1
Cereal/legumes mixture	0,5
Clover	0,85
Lucerne	0,9
Seradella	0,8
Other leguminous	0,8
Clover/grass mixture	0,5
Lucerne/grass mixture	0,55
Grass/leguminous mixture	0,3

Biological fixation = yield * standard N uptake * coeff. of biol. fixation

By-products incorporation


(fot. A. Harasim)

Amount of NPK incorporated

=

by-product yield * standard NPK uptake

Nutrient balance

Nutrient balance is calculated as a difference between total input from different sources and removal:

Ndiff = (Nmin + Norg + Ndep + Nbiol + N by-prod) – Noff

Where: Nmin – mineral fertilizers

Norg – manures, organic fertilizers, soil improvers etc.

Ndep – N atmospheric deposition

Nbiol – N biologically fixed

Nby-prod – by-products incorporated into the soil

Noff – total off-take by plants

Output of Macrobil tool

Bilans składników w gospodarstwie

Bilans gospodarstwa | Wskaźniki gospodarstwa

Elementy bilansu	Azot	Fosfor		Potas	
Dopływ	kg N	kg P	kg P2O5	kg K	kg K2O
Nawozy mineralne	3500	1965	4500	3738	4500
Odchody zwierząt	78	21	48	59	71
Obornik z obory głębokiej	1104	271	621	1273	1533
Obornik z obory płytkiej	50	23	53	47	57
Gnojówka	[illegible]	0	0	0	0
Gnojowica	0	0	0	0	0
Słoma roślin strączkowych	0	0	0	0	0
Słoma roślin oleistych	0	0	0	0	0
Liście roślin korzeniowych	617	69	158	755	909
Słoma zbóż	771	133	305	1246	1500
Wiązanie biol. N motylkowate	0				
Opad N z atmosfery	616				
Całkowity dopływ	**6734**	**2482**	**5684**	**7118**	**8570**
w tym z nawozów naturalnych	1230	315	721	1379	1660
Odpływ					
Pobranie przez rośliny	6496	1197	2741	4276	5148
Całkowity odpływ	**6496**	**1197**	**2741**	**4276**	**5148**
Saldo					
Saldo bilansu	**238**	**1285**	**2943**	**2842**	**3422**
Saldo bilansu na 1 ha	**5**	**29**	**67**	**65**	**78**
Dopływ / Odpływ	**1.04**	**2.07**	**2.07**	**1.66**	**1.66**
Współczynnik wykorzystania	**96**	**48**	**48**	**60**	**60**

NIG: **090987644**
Rok: **2015**

Gospodarstwo:
Kowalski

Zestawienie gospodarstw

Drukuj

Zamknij

Overall concept of nutrient balance at farm level

Inputs are the masses of nutrients brought onto the farm in the form of:

Purchased materials:

1. Mineral fertilisers
2. Industrial feedstuffs
3. Breeding and replacement animals
4. Other agricultural inputs, for example, manure, straw, seed
5. Biological fixation by plant material (legumes)
6. Atmospheric deposition
7. Biological fixation in soil by non-symbiotic microorganisms (nitrogen).

Outputs are the masses of nutrients leaving the farm in the form of:

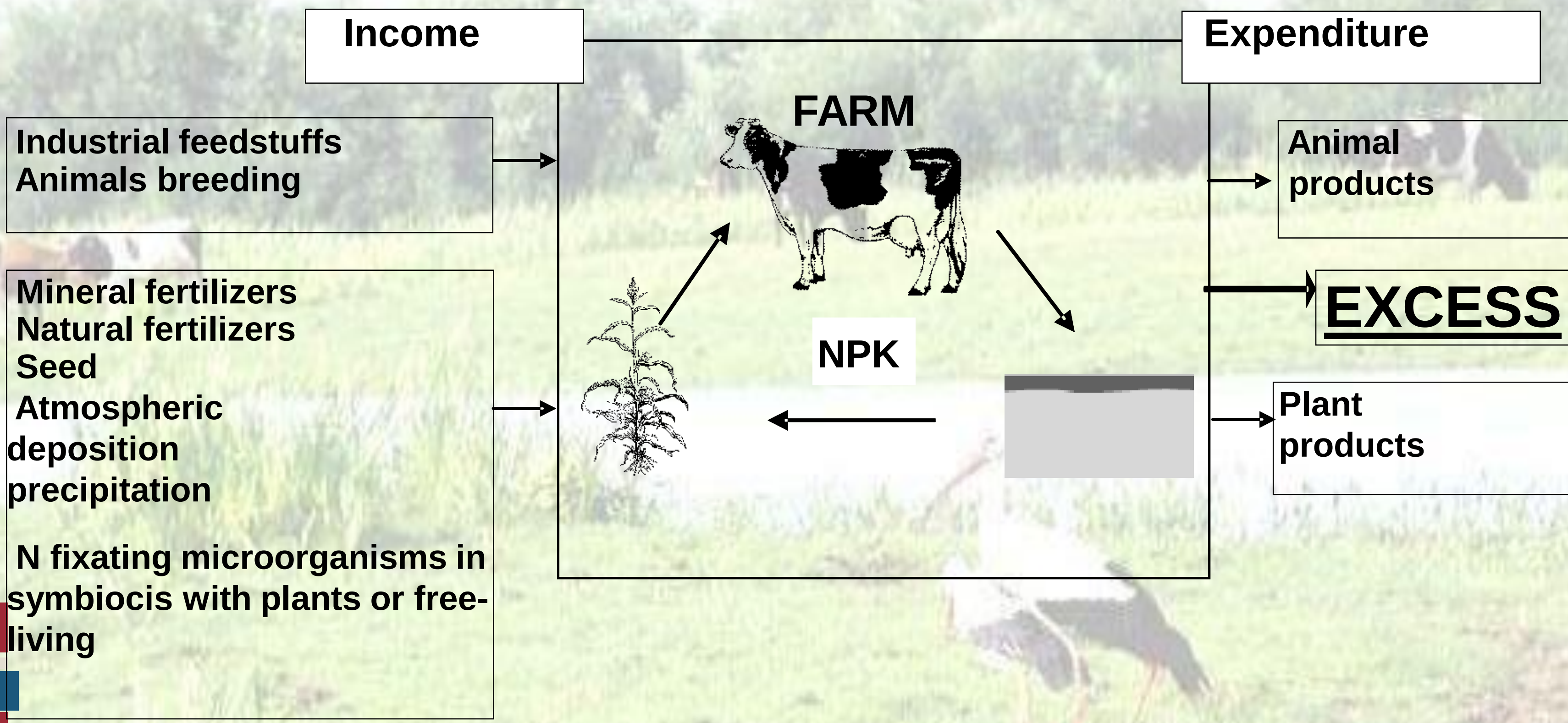
Products sold:

1. Plant products (e.g. cereals, potatoes, sugar beet, oilseed, fruits, vegetables etc.)
2. Animal products (live animal, milk, eggs, wool, etc.);

Random events, such as fallen animals, accidental crop destruction (e.g. by fire or flooding).

The difference between inputs and outputs is defined as the balance (surplus or deficit).

Overall concept of nutrient balance at farm level



Equation of nitrogen balance, the method "at the gates of the farm"

$$M_{wno} = M_{wyn} + M_{str}$$

gdzie:

- M_{wno} - nitrogen mass brought to the farm [kg],
- M_{wyn} - nitrogen mass, taken out from the farm with agricultural products [kg],
- M_{str} - excess nitrogen [kg]

Źródło: http://www.freefoto

Balance equation:

$$M_{wno} = m_n + m_p + m_o + m_m + m_g + m_x$$
$$M_{wyn} = m_s + m_v$$

where it means :

- m_n - nitrogen mass brought with mineral fertilizers [kg],
- m_p - nitrogen mass brought in industry feed [kg,]
- m_x - nitrogen mass brought in other purchased products [kg],
- m_o - nitrogen mass contributed with atmospheric precipitation [kg],
- m_m- nitrogen mass contributed by legume plants [kg],
- m_g - nitrogen mass contributed by nonsymbiotic soil microorganisms [kg],
- m_s - nitrogen mass exports with sales of agricultural products [kg],
- m_v - nitrogen mass exports as a result of the mishap and accidents [kg].

The formula for nitrogen surplus :

$$M_{str} = M_{wno} – M_{wyn}$$

Content of nitrogen (N), phosphorus (P) and potassium (K) in various commercial mineral fertilisers

Name of fertilizer	N	P	K
	kg·dt^{-1} (%)		
Mocznik	46	0	0
Polifoska 8	8	10,5	19,8
RSM - ciekły nawóz saletrzano - mocznikowy	32	0	0
Saletra amonowa	34	0	0
Saletrzak	27,5	0	0
Sól potasowa granulowana	0	0	49,6
Superfosfat potrójny granulowany	0	20,1	0

Content of nitrogen (N), phosphorus (P) and potassium (K) in various types of organic fertilisers

Name of fertilizer	N	P	K
	$kg \cdot dt^{-1}$ (%)		
Manure from cattle - in general	0,47	0,122	0,537
Manure from pigs - in general	0,53	0,205	0,570
Manure from horses	0,54	0,127	0,785
Manure from sheep	0,76	0,175	1,033
Urine from cattle - in general	0,32	0,013	0,661
Urine from pigs - in general	0,28	0,017	0,339
Urine from horses	0,47	0,002	0,463
Slurry from cattle - in general	0,34	0,087	0,306
Slurry from pigs - in general	0,43	0,144	0,190

Content of nitrogen and phosphorus in industrial feeds

Name of the industrial feeds	N	P
	kg·dt^{-1} (%)	
Mieszanka „B-w” dla krów wysokomlecznych bez mocznika	3,76	0,8
Koncentrat „KBC” dla bydła i owiec bez mocznika	5,44	1,2
Mieszanka „L” dla loch	2,80	0,9
Koncentrat „Provit” dla trzody chlewnej	6,56	2,4
Koncentraty „T” i „TR” dla tuczników	4,80	2,0

Mass of nitrogen bring to the farm with mineral fertilizers - mn, industrial feeds - mp and in other bought products - mx

$$m_n = \sum m_{ni} \cdot k_{Ni} \text{ [kg]}$$

$$m_n = m_{n1} \cdot k_{N1} + m_{n2} \cdot k_{N2} + m_{n3} \cdot k_{N3} + \ldots \text{ [kg]}$$

Where it means:

m_n – mass of the fertilizer, w kg,

k_{Ni} - content of nitrogen in fertilizer

$$m_p = \sum m_{pi} \cdot c_{Ni} \text{ [kg]}$$

$$m_p = m_{p1} \cdot c_{N1} + m_{p2} \cdot c_{N2} + m_{p3} \cdot c_{N3} + \ldots \text{ [kg]}$$

Where it means :

m_p – mass of the industrial feed, w kg,

c_{Ni} - content of nitrogen in feed

$$m_x = \sum m_{xi} \cdot t_{Ni} \text{ [kg]}$$

$$m_x = m_{x1} \cdot t_{N1} + m_{x2} \cdot t_{N2} + m_{x3} \cdot t_{N3} + \ldots \text{ [kg]}$$

Where it means :

m_{xi} – mass of the purchased products , in t or dt,

t_{Ni} - content of nitrogen .

Mass of the nitrogen inputs with atmospheric precipitation - mo

$$m_o = p \cdot S \text{ [kg]}$$

Where it means :

p - estimated amount of nitrogen transferred with atmospheric precipitation, in kg/ha; for Poland p = 15-25 kg/ha [Sapek, 1995], average 17 kg/ha,

S – surfers of farm, w ha.

Atmospheric deposition inputs of nitrogen (N), phosphorus (P) and potassium (K) in Poland in 2011.

Province	Amount, kg/ha/year		
	N_{tot}	P_{tot}	K
Dolnośląskie	10.36	0.268	2.24
Kujawsko-pomorskie	9.05	0.308	1.66
Lubelskie	10.71	0.307	1.90
Lubuskie	10.00	0.375	1.77
Łódzkie	8.83	0.238	1.90
Małopolskie	12.52	0.295	4.36
Mazowieckie	12.01	0.362	2.04
Opolskie	10.72	0.293	2.96
Podkarpackie	14.08	0.457	2.65
Podlaskie	11.49	0.620	1.87
Pomorskie	9.75	0.397	2.63
Śląskie	10.12	0.318	3.09
Świętokrzyskie	10.67	0.284	2.94
Warmińsko-mazurskie	9.15	0.301	1.59
Wielkopolskie	11.38	0.507	2.57
Zachodniopomorskie	11.77	0.514	2.31
Poland	10.85	0.378	2.30

The mass of nitrogen brought by legume plants- mm

$$m_m = \sum P_i \cdot Q_i \cdot b_{Ni} \text{ [kg]}$$

Where it means :

P_i - surface of a field with legumes species, in ha,

Q_i - the yield of the aerial parts of a species of legumes (in fresh weight) or seeds, in $t \cdot ha^{-1}$ (yield above-ground parts of legumes occurring in mixtures with grasses, can be approximated as: *yield of green mass of the mixture x share of legumes in the sward*)

b_{iN} - the amount of nitrogen bound by legumes per 1 ton of green mass yield of aboveground parts or seeds, in kg w kg $N \cdot t^{-1}$

Source: http://www.soils.wisc.edu/extension/shortcourse/2007/componentsNMplan.pdf

Amount of nitrogen (N) fixed by legume plants - mm

Plants	Amount if nitrogen fixed by legume plants - b_{iN} calculated on:	
	1 ton of green mass yield of aboveground parts, kg N · (1 t yield of aerial parts of plants)$^{-1}$	1 ton of seeds, kg N·(1 t seeds)$^{-1}$
In the main crop *		
yellow lupin	5,1	-
pea	5,2	-
serradella	5,3	-
In cultivation for seeds		
green pea	-	40,5
vetch beans	-	60,0
In intercrops		
yellow lupin	6,1	-
pea	5,0	-
serradella	4,3	-
winter wetch	5,0	-

Calculated on a basis of: Nawozy…, 1967; Wyniki.., 1973; Azot.., 1991; Schmidtke, 2008

Total amount of nitrogen (N) fixed by monoculture perennial legumes and mixes legume:grass leys (kg N/t aboveground biomass) [Modified based on : Høgh-Jensen i in., 2004]

Total amount of nitrogen (N) fixed by monoculture perennial legumes and mixed legume: grass leys (kg N/t aboveground biomass)			
Cultivated plants	Land use	Amount of N_2 fixed by plants in :	
		Clay soil	Sandy soil
One-year or two-year lucerne in monoculture	Hay	7.4	6.2
One-year or two-year red clover in monoculture		8.2	6.8
One-year or two-year mixed white clover:grass ley		17.2	14.2
One-year or two-year mixed red clover:grass ley		10.2	8.8
More than two-year mixed white clover:grass ley		15.0	11.8
One-year or two-year mixed white clover:grass ley	Grazing	16.8	14.4
One-year or two-year mixed red clover:grass ley		9.6	8.4
More than two-year mixed white clover:grass ley		13.0	10.6

Mass of nitrogen input by soil microorganisms - m_g

$$m_g = a \cdot S \text{ [kg]}$$

Where it means :

a - the amount of nitrogen brought by soil microorganisms, in kg N / ha (average a = 10 kg N / ha),

S – area of the farm, in ha.

Studies have shown that the number of species of free-living bacteria in the soil, having the ability to bind atmospheric nitrogen is more than 150. The most famous are the bacteria of a kind *Azotobacter* and *Clostridium*

Mass of nitrogen input by soil microorganisms - m_g

Amount of nitrogen (N) fixed by microorganisms present in different types of soil	
Soil	**Amount of N fixed, kg N/ha/year**
Podozolic soil	**7.5–9.5**
Grey forest soil	**18.9–24.5**
Black soil (chernozem)	**35.0–42.0**
Chestnut soil	**19.0–24.0**
Serozem	**19.0–24.0**
Mean value for Poland	**10.0**

Modified based on MAZUR [1991, after Beresteckim 1988].

Mass of nitrogen exports with sales of agricultural products - m_s

$$m_s = \sum m_{si} \cdot n_{Ni} \text{ [kg]}$$

$$m_s = m_{s1} \cdot n_{N1} + m_{s2} \cdot n_{N2} + m_{s3} \cdot n_{N3} + \ldots \text{ [kg]}$$

Where it means:

m_{si} - the mass of sold products in dt,

n_{Ni} - the amount of nitrogen contained in the each products.

Amount of nitrogen (N), phosphorus (P) and potassium (K) in different types of agricultural products w kg/100 kg

Type of product	n_{Ni} (p_{Ni})	n_{Pi} (p_{Pi})	n_{Ki} (p_{Ki})
Grain mixtures (grain)	1,80	0,35	0,43
Sugar beet	0,208	0,04	0,20
Potatoes	0,35	0,05	0,48
Milk	0,54	0,10	0,15
Eggs	1,94	0,20	0,125
Dairy cattle (550 kg)	2,50	0,74	0,17
Slaughter pigs (110 kg)	2,60	0,46	0,22
Straw	0,70	0,10	1,00

na podstawie różnych źródeł, głównie [Fagerberg B., Salomon E., Steineck S, 1993].

Excess and efficient use of nutrients on the farm

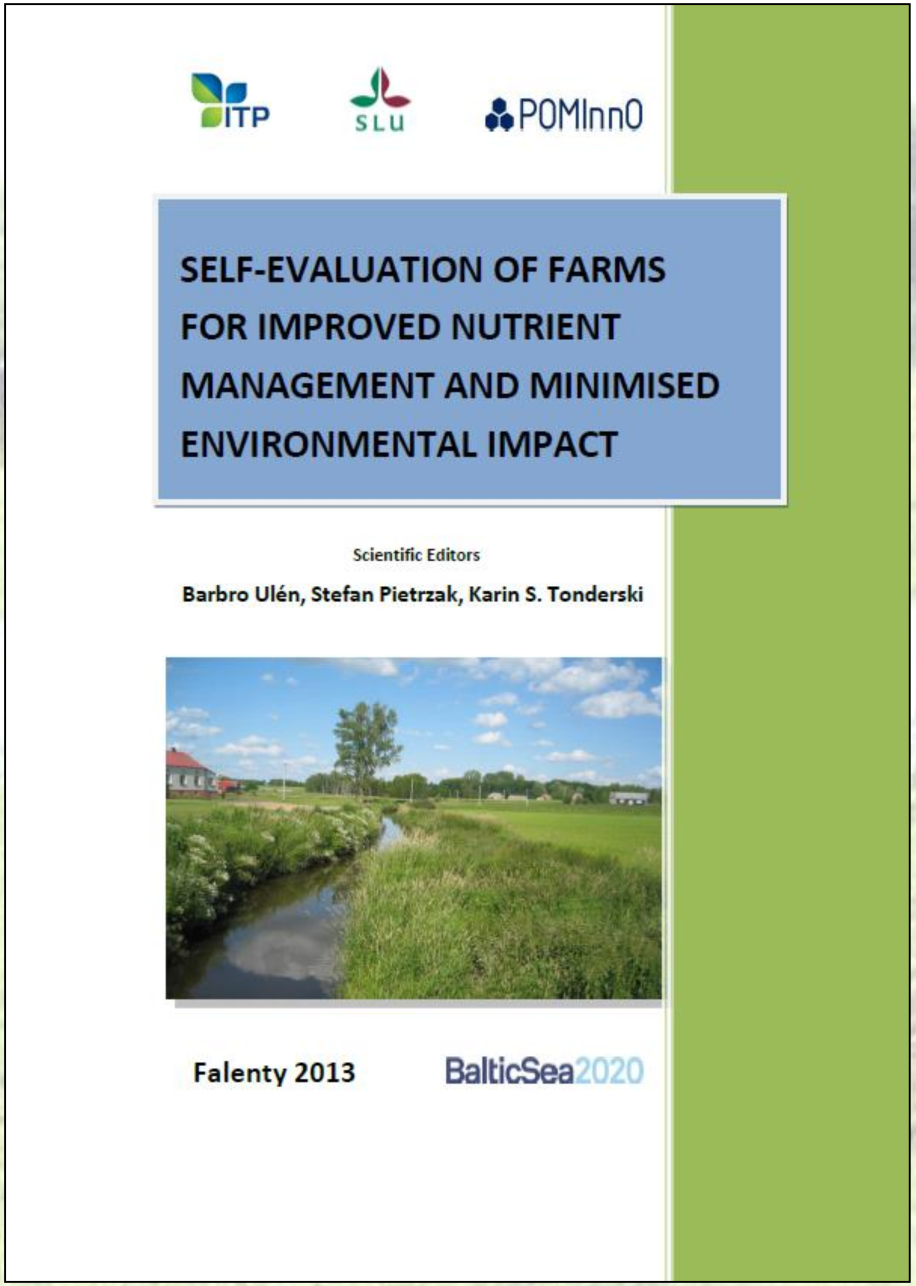
$$M_{str} = M_{wno} - M_{wyn}$$

$$E = (M_{wyn} : M_{wno}) \cdot 100$$

Where it means:

- M_{wno} - the mass of nitrogen brought to the farm [kg],
- M_{wyn} - the mass of nitrogen taken away from farm with the agricultural products [kg],
- M_{str} - excess nitrogen (nitrogen surplus) [kg]
- E – efficient of use, %

http://www.balticsea2020.org/english/images/Bilagor/2014%20Guide%20-%20Self-evaluation%20of%20farms.pdf



Thank you very much for your attention!