AGROECOLOGY FOR SUSTAINABLE AGRICULTURE AND FOOD SYSTEMS

BORIS BOINCEAN

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- **BORIS BOINCEAN, doctor habilitate of agricultural sciences, research professor; Head of the Department of Sustainable Farming Systems at Selectia Research Institute of Field Crops; Chief of the Chair of Natural Sciences and Agroecology at Alecu Russo Balti State University, Republic of Moldova**
- **Agronomist**
- **Native language – Moldavian (Romanian)**

Studies

- **Moscow Agricultural Academy by name of K.A. Timiriazev (1978), Faculty of Agronomy (Russia)**
- **PhD on soil organic matter transformation on arable soils in non-chernozem soils of Russia (1982)**
- **Doctor habilitate on crop rotations and soil organic matter on Chernozems of Moldova, defended at the same Moscow Agricultural Academy by name of K.A. Timiriazev**

Work experience:

- Since 1982 working at Selectia Research Institute of Field Crops (RIFC), Balti, Republic of Moldova
- Senior research worker (1983-1984); scientific secretary of the RIFC (1985-1990); research director (1993-1999); General Director of Scientific Production Agrifirm and director of the RIFC (1999-2009)
- Chief of the Chair of Natural Sciences and Agroecology at Alecu Russo Balti State University since 2003
- Honorable member of Romanian Academy of Agricultural Sciences, Distinguished scientist of the Republic of Moldova; expert at National Council for the Attestation and Accreditation; expert at the European Commission for Horizon 2020 etc

Agriculture in all over the world is facing many challenges at the moment and especially in the future:

- **Limited natural resources, including nonrenewable sources of energy (oil, natural gasses, coal) with regularly increased prices on them**
- **Worsening of economic conditions for farmers activities because of unfair increased prices for industrial inputs and agricultural products**
- **Providing food security at the local, regional and global levels in the conditions of higher density of population**
- **Biodiversity losses including genetic losses both on the surface of the soil and, especially, in the soil**
- **Soil degradation and the danger of ground waters and food pollution on the whole food chain in the conditions of the globalization of economy**
- **Increased negative consequences of the global warming with more frequent manifestation of droughts (heats) and other natural calamites**
- **Rural community disintegration**
- **Increased expenses for public health (notransmisible diseases)**

Fig. 1 Yields of winter wheat in the Republic of Moldova, average for 1962-2015

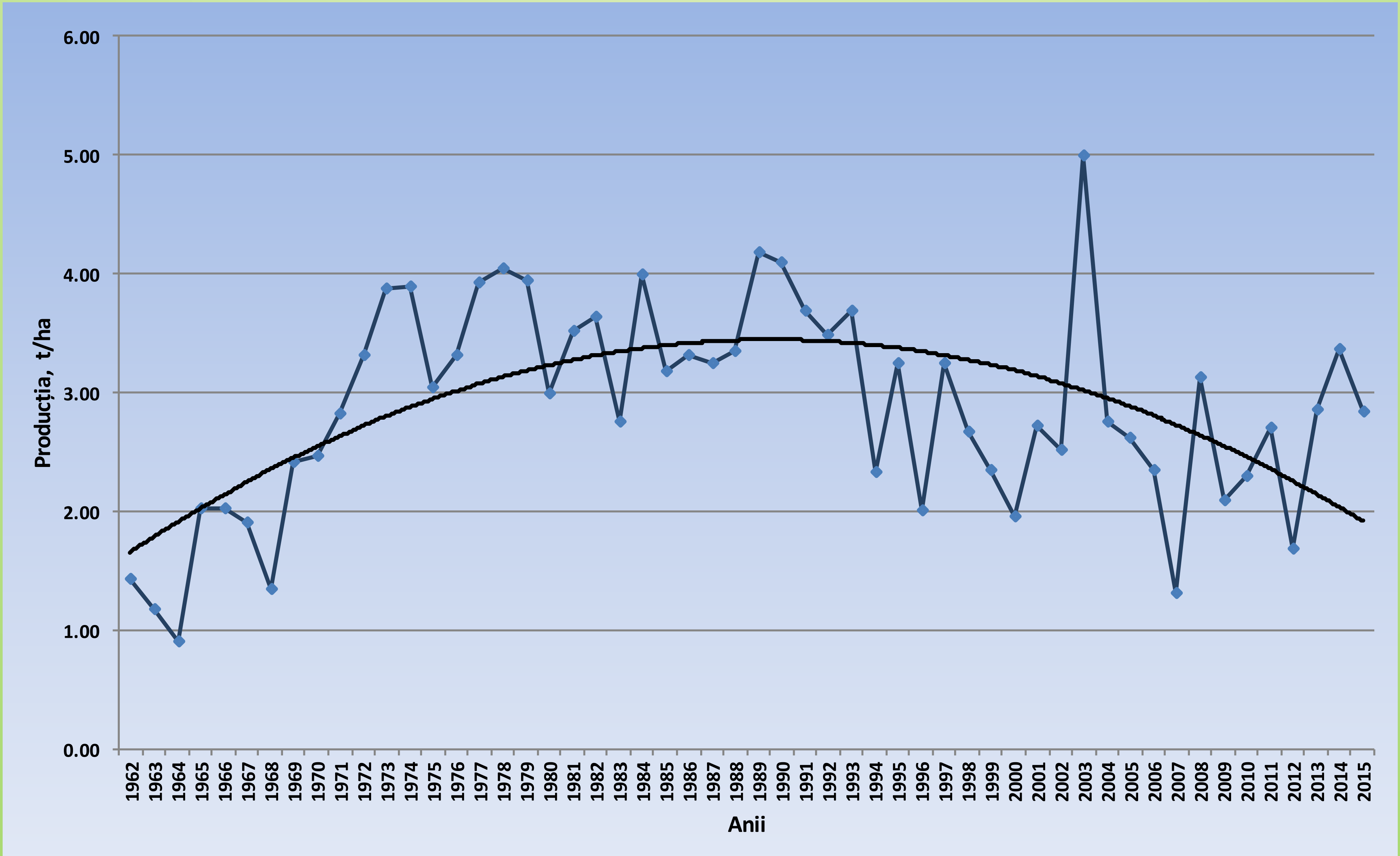


Fig. 2 Yields of winter wheat in the long-term field experiment at Selectia Research Institute of Filed Crops , average for 1962-2015

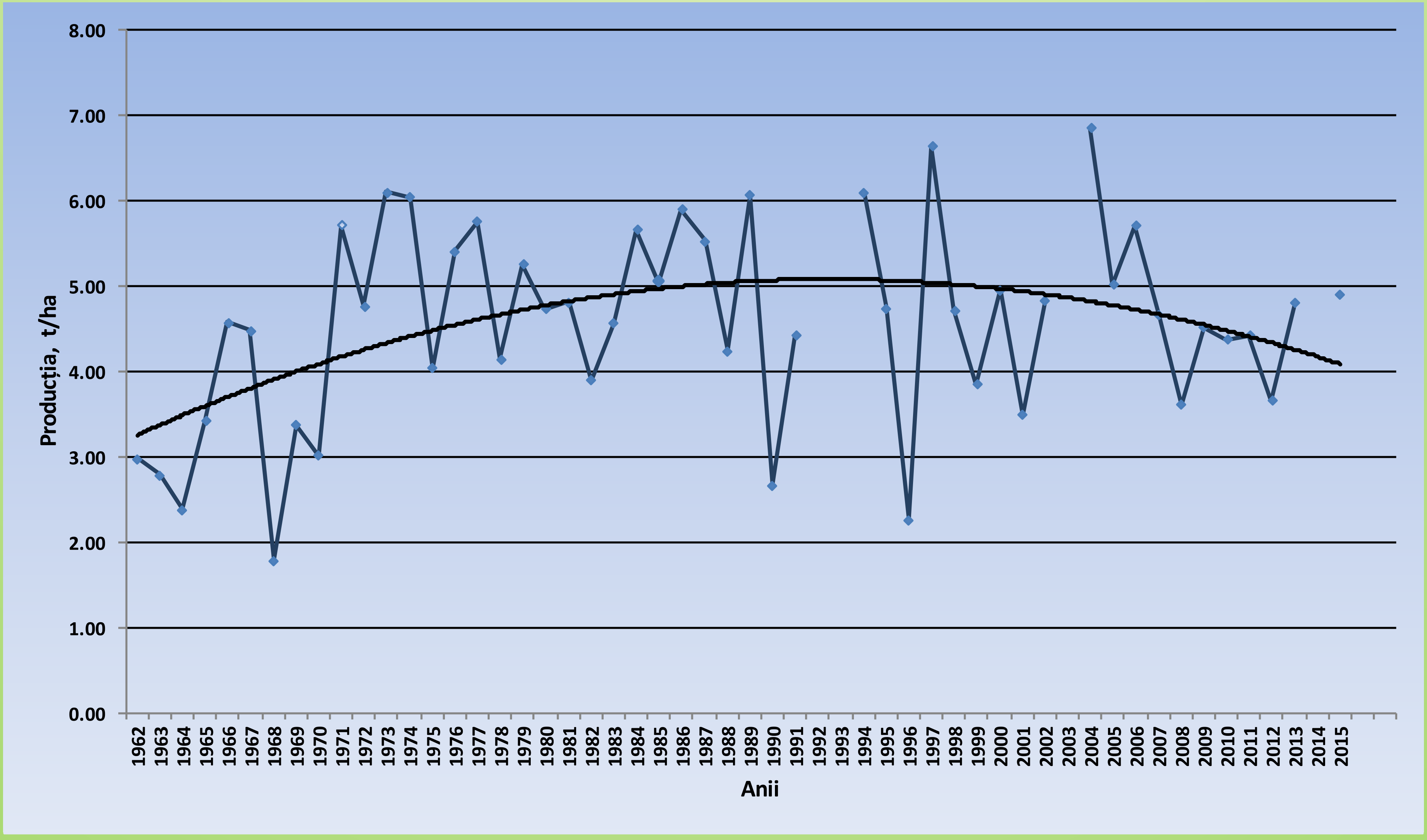
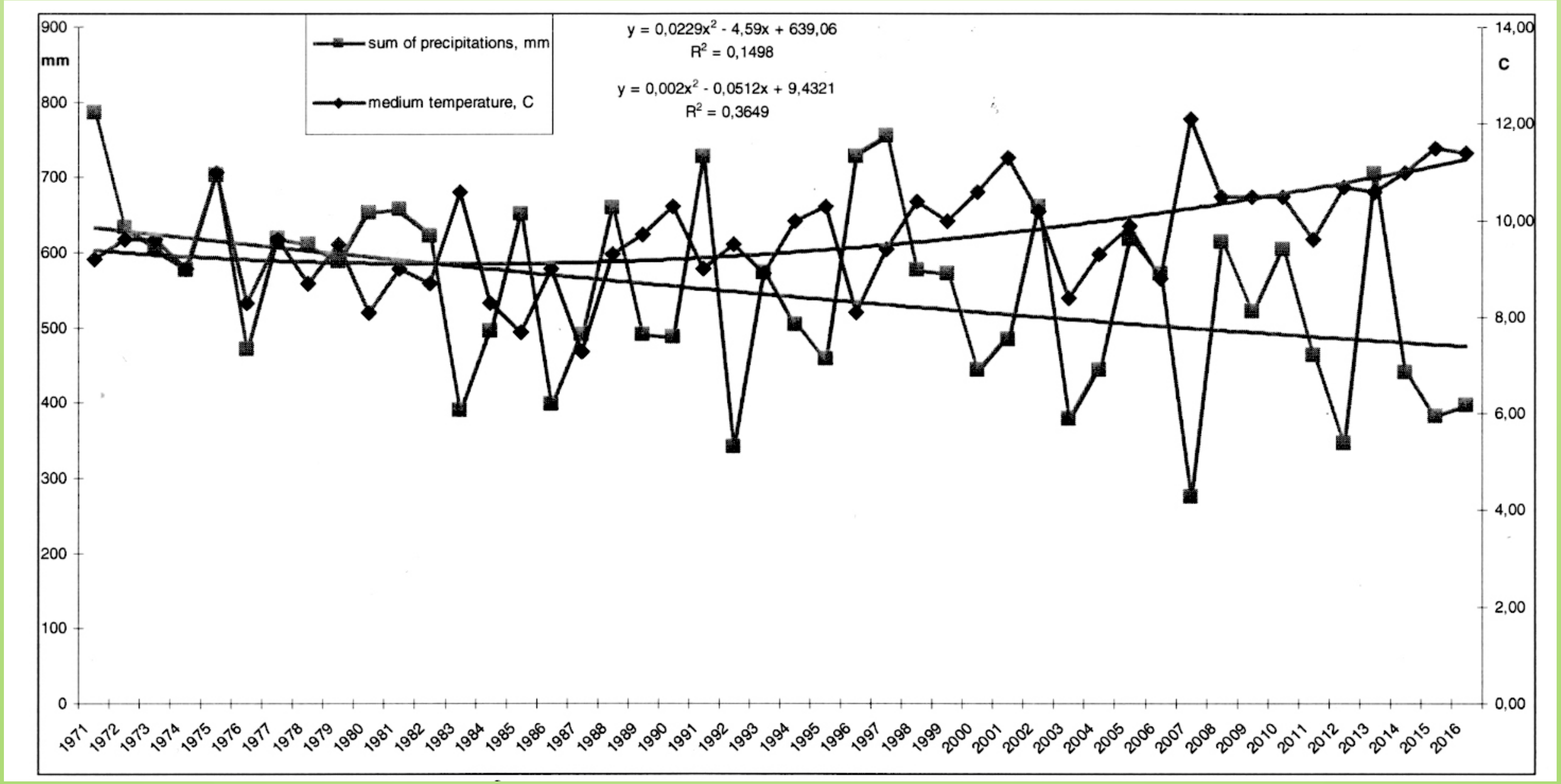
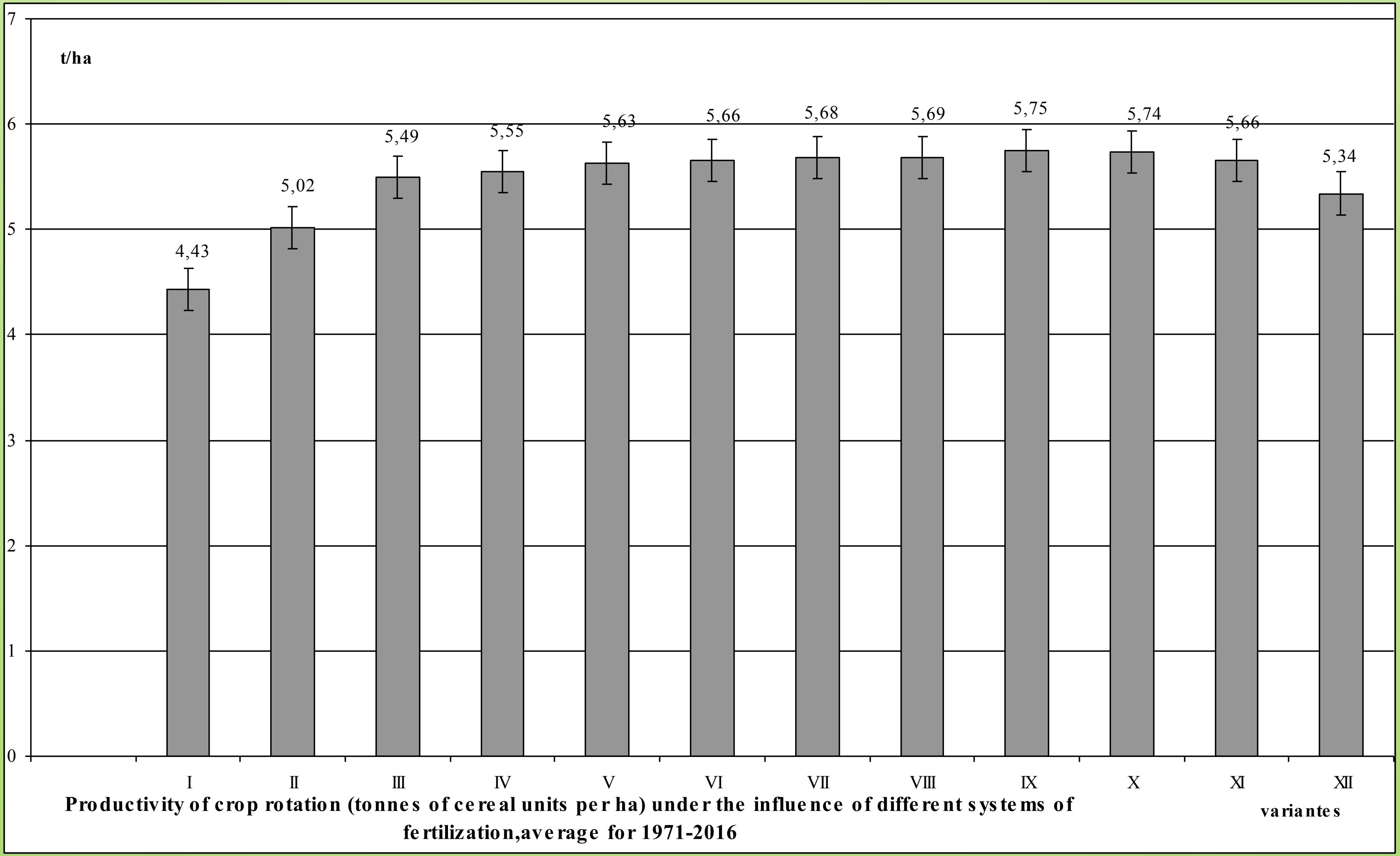


Fig.7.10 Trends for atmospheric precipitations and air temperature for the Balti Steppe regions, Republic of Moldova for 1970-2016. Data from Meteorological Station of Selevetia Research Institute of Field Crops

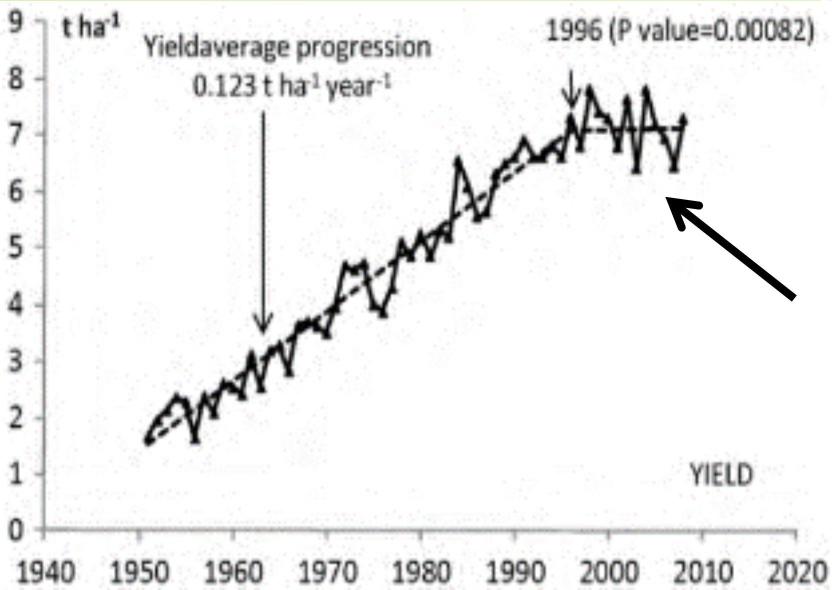


Productivity of crop rotation (Mg/ha) under the influence of difference systems of fertilization, average for1971-2016



Stagnating Yields (yield gap)

Rising-plateau regression analysis of wheat yields throughout various European countries



Country	Year of stagnation
Denmark	1995 (**)
France	1996 (**)
Germany	1999
Italy	1994
Netherlands	1993 (**)
Spain	1989
Switzerland	1990 (**)
United Kingdom	1996 (**)

(Brisson et al. 2010)

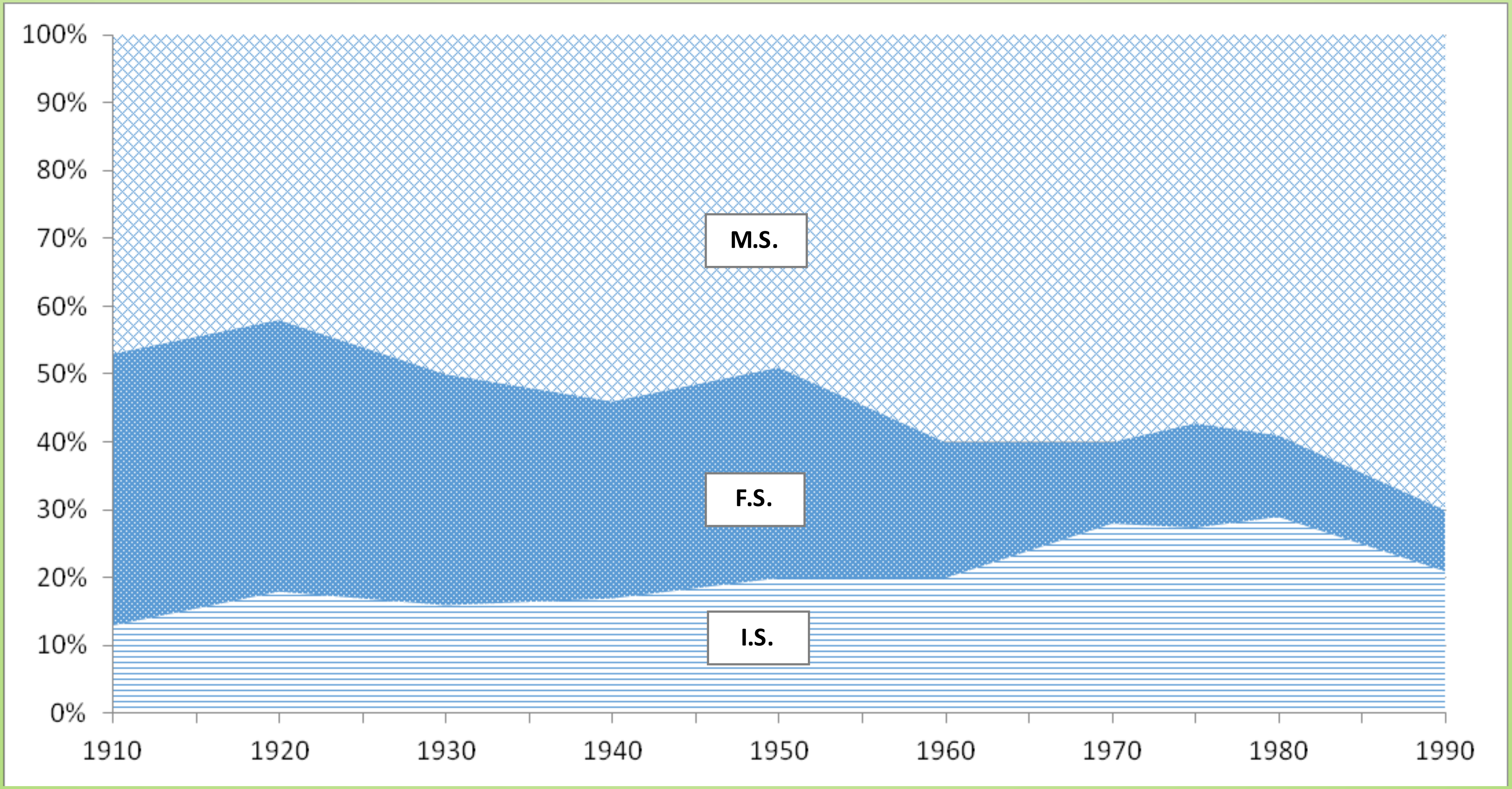


Fig. 4 Distribution of profit between the three sectors of agroindustrial complex (according prof. S. Smith, 1991)

I.S. – input sector

F.S. – farming sector

M.S. – marketing sector (processing, packaging, transportation, marketing)

Discrepancy between prices for non-renewable and limited sources of energy and prices for agricultural products is aggravating the economic, ecologic and social situations in agriculture

- **In 1995 farmers would buy 1 ton of diesel fuel by selling 1 ton of winter wheat grain**
- **In 2018 farmers can buy only 180 liters of diesel fuel from selling 1 ton of winter wheat grain**
- **In 1995 farmers would buy 1 ton of nitrate ammonium by selling 250 kg of winter wheat**
- **In 2018 farmers can buy only 380 kg of nitrate ammonium by selling 1 ton of grain of winter wheat**

The same regularity is for the other industrial inputs

- **Application of mineral fertilizers isn’t efficient from an economic point of view even at low rates**

Table 1.The required level of extra yields to pay off applied rates of mineral fertilizers, Selectia Research Institute of Field Crops, Balti, Republic of Moldova

CROPS	Rates of mineral fertilizers, kg a.i./ha	Extra yields obtained in average for 2011-2016, t/ha	Required level of extra yields to pay of fertilizers, t/ha
Winter wheat	NPK 75	0,64	0,91
	NPK 130	0,49	1,70
	NPK 175	0,69	1,82
Sugar beet	NPK 75	3,75	3,0
	NPK 130	4,80	5,7
	NPK 175	5,45	6,6
Corn for grain	NPK 75	0,91	1,14
	NPK 130	0,82	1,78
	NPK 175	0,26	2,56
Sunflower	NPK 75	0,27	0,40
	NPK 130	0,33	0,70
	NPK 175	0,33	0,75

- Industrial model of agricultural intensification based on the concept of “Green revolution” didn’t address many of the above mentioned challenges and consequently didn’t provide a sustainable development (economic, ecologic and social aspects). It means agriculture is in crisis.
- Conventional agriculture is built around two related goals: the externalization of the negative consequences on the environment and health of people
- Prices for agricultural products are not real prices, because they don’t take in consideration the expenses required for recovering the negative consequences on the environment and health of people
- Soil is treated as a substrate where water and nutrients are applied for obtaining yields. Food production is threatened like an industrial process, where plants assume the role of miniature factories: their output is maximized by industrial inputs and soil is simply the medium in which their roots are anchored

Soil is a living organism. Life on the earth became possible thanks to permanent turnovers of energy and nutrients on the entire natural food chain: producers – consumers – decomposers (will of life according Howard in "Agricultural Testament" (1943). The crucial role of decomposers (located in the soil) has been underestimated if not neglected until now. Meantime 95% of our food comes from the soil.

- **Soil playing a polyfunctional role in providing ecosystem and social services**
  - **Water purification**
  - **Habitat for a large soil biodiversity on the whole trophic chain**
  - **Crop productivity**
  - **Pollination for crops**
  - **Reduction of global warming through carbon sequestration etc**
- **Agriculture in all over the world requires change of the paradigm of agricultural intensification – transition from industrial inputs to a better recycling of energy and nutrients in each farm**

Tab. 2 The yields of winter wheat after different predecessors in crop rotation and in permanent mono-cropping, average for 1994-2016, long term field experiments at Selectia Research Institute of Field Crops, Republic of Moldova, t/ha and %

Crop rotation, permanent mono-cropping	Predecessors	Fertilization		± from fertilization, t/ha / %	Yield reduction relatively to mixture of vetch and oats for green mass	
		Unfertilized	Fertilized		Unfertilized	Fertilized
Crop rotation	Mixture of vetch and oats for green mass	4,56	5,02	+0,46/10,1	-	-
	Corn for silage	3,35	4,56	+1,21/36,1	-1,21/26,5	-0,46/9,2
	Corn for grain	2,67	3,66	+0,99/37,1	-1,89/41,5	-1,36/27,1
Permanent mono-cropping	**Winter wheat**	**1,98**	**2,96**	**+0,98/49,5**	**-2,58/56,6**	**-2,06/41,0**

Tab.3 The share of soil fertility in yield formation (%) in crop rotation and permanent mono-cropping for winter wheat , average for 1994-2016, Selectia RIFC

Crop rotation, permanent mono - cropping	Predecessors	Fertilization	
		Fertilized	Unfertilized
Crop rotation	Mixture of vetch and oats for green mass	83,9	100
	Corn for silage	63,9	100
	Corn for grain	62,9	100
Permanent mono-cropping	Winter wheat	50,5	100

Tab. 4 Nitrogen use efficiency (%) by winter wheat sown after different predecessors and in permanent mono-cropping, average for 1994-2016, Selectia RIFC, Republic of Moldova

Crop rotation, mono-cropping	Predecessors	Extra yields from fertilization, t/ha	Nitrogen taken up by extra yields, kg/ha	N applied with mineral fertilizers, kg/ha	N – use efficiency, %
Crop rotation	Mixture of oats and vetch for green mass	0,46	13,8	90	15,3
	Corn for silage	1,21	36,3	90	40,3
	Corn for grain	0,99	29,7	90	33
Mono-cropping	Winter wheat	0,98	29,4	90	32,7

Tab.5 Water – use efficiency by winter wheat sown after early harvested, late harvested predecessors and in mono-cropping, average for 2004-2013

Crop rotation, mono-cropping	Predecessors	Stocks of soil moisture in the spring (mm) for 0-200 cm soil layer	Stocks of soil moisture after harvesting (mm) in 200 cm soil layer	Soil moisture consumption, mm	Precipitation during growing period of winter wheat (mm)	Water use efficiency from atmospheric precipitation (%)	Water use efficiency (tons of water per ton of grain)
Crop rotation	Mixture of oats and vetch for green mass	360,2	162,7	197,5	441,8	44,7	419,9
	Corn for silage	328,4	146,4	181,8	441,8	41,1	502,2
	Corn for grain	430,4	157,5	272,9	441,8	61,8	723,9
Mono-cropping	Winter wheat	364,9	186,3	178,6	441,8	42,5	622,3

Tab.6 Yields of corn for grain in crop rotation and monoculture (t/ha) on different systems of fertilization, Urbana, Illinois, USA (Koepf H., 1992)

Fertilization	Mono-cropping of corn for grain	Crop rotations	
		Corn-oats	Corn-oats-clover
Since 1904 to 1954			
Unfertilized (background 1)	2,52	2,17	3,96
Manure, lime, P_2O_5 (background 2)	4,26	6,82	7,30
Since 1954 to 1964			
Background 1+NPK	5,67	6,24	6,90
Background 2+NPK	6,39	7,04	7,24

- The higher is the biodiversity of crops in the crop rotation the higher is the functionality of soil as a result of a larger biodiversity of organisms for the whole soil food chain
- Lack of knowledge or simplification of crop rotation can't be compensated by higher rates of mineral fertilizers and pesticides
- By respecting crop rotation it is possible to:
  - Maintain and increase crop yields
  - Reduce the production expenditures through cutting the dependence from mineral fertilizers, especially nitrogen, for crop nutrition and pesticides for weeds, pests and deseases control

Tab. 7 “Effect of crop rotation” in the long-term field experiments of Selectia RIFC (Balti, Republic of Moldova), average for 15 years, t/ha and %

Crops	Indices	10 fields crop rotation		7 fields crop rotation		Permanent mono-cropping	
		Unfertilized	Fertilized	Unfertilized	Fertilized	Unfertilized	Fertilized
Winter wheat	t/ha	4,64	5,06	3,96	4,29	1,95	2,84
	± t/ha and %	+2,69/ 137,9%	+2,22/ 78,2%	+2,01/ 103,1%	+1,45/ 51,1%		
Sugar beet	t/ha	33,21	43,00	23,00	38,55	9,05	17,81
	± t/ha and %	+24,16/ 267,0%	+25,19/ 141,4%	+13,95/ 154,1%	+20,74/ 116,5		
Corn for grain	t/ha	5,22	5,67	5,01	5,62	3,75	5,16
	± t/ha and %	+1,47/ 39,2	+0,51/ 9,9%	+1,26/ 33,6%	+0,46/ 8,9%		
Sunflower	t/ha	1,99	2,14	1,40	1,70	1,42	1,56
	± t/ha and %	+0,57/40,1%	+0,58/ 37,2%	-0,02	+0,14/ 9,0%		

Tab. 8 The influence of different systems of soil tillage and fertilization in crop rotations with and without mixture of legumes and grasses, t/ha and %

Systems of soil tillage	Crop rotation without perennial crops			Crop rotation with perennial crops		
	Control (without fertilization)	Farmyard manure	Farmyard manure +NPK	Control (without fertilization)	Farmyard manure	Farmyard manure +NPK
Winter wheat						
Moldboard plow	2,85	3,30	4,10	4,40	4,44	4,51
Non-inversion tillage	2,82	3,23	4,16	4,32	4,42	4,55
Difference (± and %)	-0,03/1,1%	-0,07/2,1%	+0,06/1,5%	-0,08/1,8%	-0,02/0,5%	+0,04/0,9%
Corn for grain						
Moldboard plow	4,76	4,99	5,06	5,14	5,14	5,31
Non-inversion tillage	4,74	4,82	4,93	5,10	5,11	5,20
Difference (± and %)	-0,02/0,4%	-0,17/3,4%	-0,13/2,6%	-0,04/0,8%	-0,03/0,6%	-0,11/2,1%

Tillage-induced Carbon Dioxide Loss and wind erosion

Reicosky

Conservation Agriculture is based on the practical application of three interlinked principles of:

1. **Continuous no or minimum mechanical soil disturbance (no-till seeding/planting and no-till weeding)**
2. **Permanent maintenance of soil mulch cover (crop biomass, stubble and cover crops)**
3. **Diversification of cropping system (rotations and/or sequence and/or association involving annuals and perennials, including legumes), along with other complementary agricultural production management practices**

   (more at: www.fao.org/ag/ca)

- **In order to be sustainable agriculture must reverse the process of soil degradation**

- **Soil quality (soil health) is crucial in the transition to a more sustainable agriculture, including to organic (ecologic, biologic) agriculture**
- **A good quality soil can provide besides a relevant crop production such ecosystem and social services as:**
  - **Filtering and purifying water before it is released to waterways**
  - **Inorganic and organic pollutants can be absorbed and some can be degraded**
  - **Buffer for climate changes by promoting the growth of plants that sequester CO_2 from the atmosphere and contributing to the humification and physical protection of carbon from plants and other organic residues**
  - **Healthy soil provides health for the whole trophic chain: soils-crops-animals-people**
  - **Changing the habits to eat will stimulate transition to a more sustainable agriculture**

- **Soil organic matter is the integral index of soil fertility**
- **A decline in soil organic matter following intensive tillage can reduce the water-holding capacity of the soil, making crops more susceptible to water deficit and drought during the growing season. Droughts and erosion are two sides of the same coin**
- **Changes in the soil structure due to compaction by heavy farm equipment suppress root development, thus reducing the quantity of soil nutrients and water that can be accessed by crops**
- **A soil with good physical, chemical and biological properties is able to produce higher crop yields and to generate more income than a poor- quality soil**

- **<u>Agroecology as a basis for sustainable agriculture</u>**

- **Agroecology is the application of ecological concepts and principles to the design and management of sustainable agroecosystems**
- **The agroecological approach to agriculture builds on the resource-conserving aspects of local and small-scale agriculture**
- **Agroecology supposes a holistic (systemic) approach to agricultural intensification instead of a reductionistic (simplistic) approach**
- **Preventing is significantly more effective than controlling the consequences of mistakes made in designing the farming system**
- **Agroecology is based on using natural ecosystems as models for agroecosystems**

Tab. 9 Structural and functional differences between natural ecosystems and agroecosystems (Odum, 1969 and Gliessman, 2000)

Indicators	Natural ecosystems	Agroecosystems
Net Productivity	Medium	High
Trophic interaction	Complex	Simple, linear
Species diversity	High	Low
Genetic diversity	High	Low
Nutrient and energy cycles	Closed	Open
Stability (resilience)	High	Low
Human control	Independent	Dependent
Temporal permanence	Long	Short
Habitat heterogeneity (ecological infrastructure)	Complex	Simple

Tab.10 Stocks and losses of soil organic matter (on carbon) for Typical Chernozem from Balti Steppe, Republic of Moldova, soil layer 0-100 cm

Soil layers, cm		Meadow (native grassland field)		Stocks and losses relative to native grassland field								
				Crop rotation with alfalfa (30%)+40% row crops			Crop rotation without alfalfa + 60 % of row crops (12 t/ha manure)			50-yrs continuous black fallow		
		t\ha	%	t/ha	±	%	t/ha	±	%	t/ha	±	%
0-100		342,3	100	273,7	-68,6	20,0	281,7	-60,6	17,7	222,3	-120,0	35,1
Including	0-60	225,3	65,8	182,2	-158,1	46,2	200,8	-141,5	41,3	161,5	-180,8	52.8
	% relative to 0-100 cm	65,8		67,3			71,3			72,6		

Tab.11 Potential for the reduction of global warming on arable soils of the Republic of Moldova, soil layer 0-100 cm

Areas under arable lands, thousands ha	Losses of carbon relative to the crop rotation without perennial crops and manure, t/ha	CO_2 Emissions t/ha (C x 3,7)	Total emissions of CO2, thousands tons
1502,6	60	222	333577,2

Thank you for your attention!