The multifunctional challenge of future agriculture
Answers from 40 years DOK research

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Introduction

Sufficient and stable crop yields are the basis for feeding a growing world population. Limited cropland, climate change, soil quality and biodiversity coupled with excessive use of non-renewable resources require new solutions for future cropping systems beyond existing management practices.

Here we compare the yield performance and the nutrient use as well as sustainability indicators of organic and conventional cropping systems in the *DOK long-term systems comparison* after 40 years of management and show *trade-offs* in organic and conventional cropping systems.

The DOK experiment

Tab. 1: DOK treatments and fertilisation from 1978 to 2019. Fertilization levels* are indicated by 1 and 2, where 1 is 50% application of 2.

Treat-ment	Fertiliser Input [kg ha^{-1} a^{-1}]			Manure	Mineral N fertilisers	System
	N / (Nmin)	P	K			
N0	-	-	-	-	-	Control
D1	48 (13)	12	89	yes	-	Bio-dynamic
O1	48 (15)	12	92	yes	-	Bio-organic
K1	86 (57)	19	124	yes	yes	Conventional
D2	95 (26)	24	179	yes	-	Bio-dynamic
O2	96 (30)	24	184	yes	-	Bio-organic
K2	171 (113)	37	248	yes	yes	Conventional
M2	121 (121)	38	246	-	yes	Conventional

* Fertilization level 2 refers to a nutrient input of manure according to two livestock units.

Conclusion and Outlook

- Fertilization, mainly N, is the main driver for yield gap between the system and determine yield levels.
- Stability is mainly determined by crop protection and not by fertilization.
- The conventional system with reduced fertilization (K1) gained higher or similar yields over all crops compared to the regular fertilized organic systems (D2, O2), but it received less absolute amounts of nutrients with fertilizers.
- However, K1 received a higher amount of mineral N forms and additional pesticides.
- Main drivers to reduce the yield gap are an improvement of N availability and a synchronization between supply and crop demand. Further improvements in weed control by smart technologies and crop protection by cultivars that are more resistant or by crop diversification will be a key measure of future management.

Results

- Mean yields of the organic systems (O; D) were lower than conventional (K, M), (Fig. 1).
- Organic potatoes yields were 65 % and wheat 79% of conventional.
- Silage maize yields achieved 87%, clover-grass 88% and soybean 100% of conventional.
- No significant negative yield trends in all systems, except for grass-clover.
- Yield stability was higher in conventional systems.

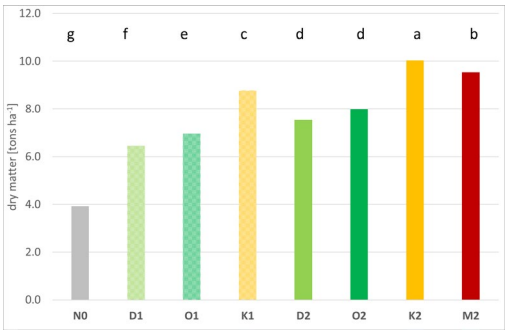

Fig. 1: Productivity of DOK treatments from 1978 to 2019. Data show mean dry matter yields of clover grass, silage maize, soybean, winter wheat and potaotes. Diff. lettters = sign. diff. of means.

- Equilibrated P and K balances at fertilization level 2 with slightly negative trends for P in organic systems.
- Negative P and K balances with low stock density at fertilization level 1 for all treatments which led to a decrease in plant available soil P and K (Tab. 2).

Tab 2: DOK Phosphorous (P) and Poatssium (K) nutrient budget from 1978 to 2019.

Nutrient		N0	D1	O1	K1	D2	O2	K2	M2
		[kg ha-1 yr-1]							
P	Input	1	11	13	19	22	26	38	39
	Output	16	24	25	30	30	30	37	34
	Balance	-15	-13	-12	-11	-8	-4	1	5
K	Input	1	91	91	128	181	181	255	248
	Output	61	126	128	173	178	178	268	232
	Balance	-60	-35	-37	-45	3	3	-13	16

- N budgets range from -20 kg to surpluses of about +55 kg N ha^{-1} yr^{-1}.
- Equilibrated N balances indicate soil N mining, while surpluses point to a risk of N losses, and/or N accumulation in the soil (Fig. 2).

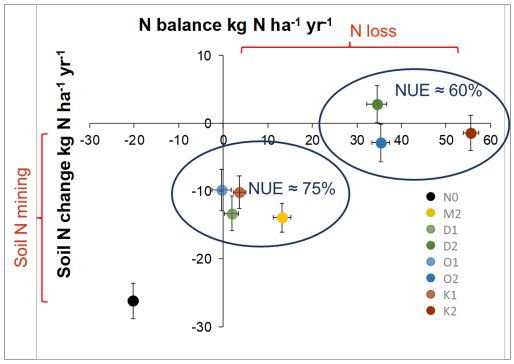

Fig. 2: Trade-off between efficiency and sustainability of N use. X-axis shows the soil surface N balance; y-axis shows the soil N stock change (0-20 cm) from 1978 to 2019.

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