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Does water availability influence the choice of a forage strategy in Swiss lowlands?

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Abstract. Swiss agricultural policy promotes grassland based forage autonomy of cattle farming. Its implementation in the lowlands should however take into account the high spatial rainfall variability. In rather dry regions, such as the South Jura foothill, full-grassland based farming may be not sustainable. This study compared five forage systems (crop rotations *versus* perennial grass-legumes mixtures) under the Geneva lake climate conditions, with and without additional water supply adapted to the plant needs. Annual crops cultivated in rotation provided the largest DM yields and were less influenced by water availability than the grass-legumes leys. Indeed, 10 mm additional water increased leys performance of 100 kg DM/ha, while the increase was only 50 kg DM/ha for maize. Effects of water availability on mineral content were less significant, but indicated a dilution of N-contents with water supply whereas K-content tended to increase. Although their mineral contents were the most balanced, yield of grass-legumes mixtures decreased significantly over the years, regardless of the availability of water. Globally, results show that annual crops cultivation can help to secure forage supply in areas prone to drought.

Keywords. Switzerland – Forage production – Water availability – Grassland – Crop rotation – Maize.

La disponibilité en eau influence-t-elle le choix d'une stratégie fourragère sur le plateau suisse ?

Résumé. *La politique agricole suisse soutient la production animale basée sur l'utilisation des prairies. Sa mise en œuvre en zone de plaine devrait toutefois tenir compte de la grande variabilité spatiale des précipitations. Dans les régions plutôt sèches, comme le pied du Jura Sud, les systèmes 'tout herbe' ne sont peut-être pas durables. Cette étude a comparé cinq variantes culturales (rotations de cultures vs. mélanges pérennes graminées-légumineuses) dans les conditions naturelles du bassin lémanique, avec et sans approvisionnement en eau adapté aux besoins des plantes. Les cultures en rotation ont fourni des rendements en matière sèche plus élevés et ont moins été influencées par la disponibilité en eau que les prairies. En effet, 10 mm d'eau supplémentaire ont augmenté la production des prairies de 100 kg de MS/ha, tandis que l'augmentation n'était que de 50 kg MS/ha pour le maïs. Les effets de la disponibilité de l'eau sur la teneur en minéraux ont été moins importants, mais ont indiqué une dilution de l'azote avec l'apport supplémentaire d'eau, tandis que la potasse augmentait. Bien que leur teneur en minéraux soit plus équilibrée, le rendement des mélanges graminées-légumineuses a considérablement diminué au cours des années, indépendamment de la disponibilité de l'eau. Globalement, les résultats montrent que les cultures annuelles peuvent sécuriser l'approvisionnement en fourrages dans les zones sujettes à la sécheresse.*

Mots-clés. *Suisse – Production fourragère – Disponibilité de l'eau – Herbages – Cultures en rotation – Maïs.*

I – Introduction

Full-grazing systems are recognised as sustainable in areas favourable for grass growth situated in the north of the Alps (Thomet *et al.*, 2011). Therefore, one objective of the Swiss agricultural policy is to reduce maize to less than 20% in the herbivorous diet. However, with climate change, grasslands will be challenged to meet this growing demand for providing forages. Despite the small size of the country, the annual rainfall varies considerably over short distances. In the Jura south foothill, lowland grasslands may be more affected by drought than mountain pastures (Mosimann *et al*., 2012; Meisser *et al*., 2014). In consequence, an extension of the maize crops is observed in the Geneva lake region where the present study was set up. We compared two forage strategies (annual crops in rotation *vs* perennial grass-legumes mixtures) under the rather dry ambient climate and under optimal watering conditions.

II – Materials and methods

The experiment started in 2009 at Agroscope in Changins, Switzerland (385 m a.s.l., 06°15' 25.1''E, 46°23'40.2''N). It was established on a 90 cm deep arable Calcaric Cambisol soil, representative of the Jura foothill. The average annual precipitation is 1000 mm and ranged between 700 and 1200 mm during the four years measurement 2010-2013. The split-plot design comprised 40 plots (12 m x 6 m) with five production variants, two levels of water supply and four replications (Mosimann *et al*., 2013).

The five production variants consisted in crop rotations (V1, V2, V3) and grasslands (V4, V5). V1 and V2 corresponded to a 2-years rotation (maize silage –winter barley– annual forage) and were offset from one another by one year. V3 consisted in a more diversified rotation with cereals and legumes annual forages. Both grassland variants (leys) were sowed in 2009 and differed by cutting frequency (V4: 7 to 8 cuts/year, local turn-out dates for grazing; V5: 5 cuts/year, usual mowing frequency).

Two levels of water supply were tested: (A) ambient conditions (rainfall); (O) optimized conditions (rainfall + additional water). On O plots, water was supplemented thanks to a drip-irrigation system with maximum daily amounts of 15 l/m² according to the soil water tension. Fertilizers were applied accordingly to the Swiss fertilization guidelines (Sinaj *et al.*, 2009).

At each harvest, biomass exported from all plots was weighted. Samples were collected and oven-dried in order to determine dry matter (DM) and mineral (N, P, K) contents. Differences between annual yields of the A and O levels of water supply were compared through pairwise comparison tests within each variant or crop.

III – Results and discussion

The results relate to four years: 2010 and 2011 were characterized by drought and large water supplements on O plots (300-500 mm/year), whereas 2012 and 2013 were much wetter with consequently reduced needs for additional water (100-300 mm/year).

Table 1 indicates that the 2-years rotations V1 and V2 obtained the highest yield, on average 17.9 t DM/ha/year in ambient condition A and 19.2 t DM/ha/year with optimised water supply O. Silage maize highly contributed to such performances (grey cells in Table 1). Mean DM production of grasslands V4 and V5 were 9.0 and 12.6 t DM/year in A and O variants. On the other hand, their yield and their botanical composition (trend not shown here) have deteriorated over time. As a consequence, V5 was resowed in spring 2012 and one year later, the newly established grass-legumes mixture achieved similar DM yield to that measured in 2010.

DM yield was generally improved by additional water supplies. For all crop variants, increase was significant in 2011 (dry year) and non-significant in 2013 (wet year). In 2013, additional water have even caused a reduction in yield for V1, but no significantly. For grassland variants V4 and V5, yield increase reached 49% in dry years (average 2010-11) and 26% in wet years (average in 2012-13). Jeangros and Calame (1992) reported similar orders of magnitude on mountain meadows, underlying the importance of a targeted irrigation.

Figure 1 shows the response of DM yield to water supply, i.e. the relationship between O and A yield differences and amounts of added water. The diagonal line indicates an increase of 1 t DM/ha with an additional water supply of 100 mm. Crops situated above this limit have a high water efficiency. Supplemental water was more profitable to ley than to maize or cereal grain. Due to their summer growth, ley and maize have high water demand during dry years and are situated on the right part of the Fig. 1.

Table 1. Total annual dry matter yield (t DM/ha/year) of the five production variants (V1 to V5), (A) without and (O) with supplemental water supply

Year	V1			V2			V3			V4			V5		
	A	O		A	O		A	O		A	O		A	O	
2010	18.9	22.0	**	19.7	20.8		8.0	9.1		11.0	16.5	***	11.9	16.9	**
2011	22.7	24.8	*	11.6	14.3	**	11.7	15.4	*	8.0	12.8	**	8.5	12.3	***
2012	16.9	17.3		22.7	24.0	**	17.0	17.2		6.3	8.7	*	5.8	10.6	**
2013	17.2	16.3		13.9	14.1		10.0	10.7		6.6	6.7		14.3	16.3	
mean	18.9	20.1		17.0	18.3		11.7	13.1		8.0	11.2		10.1	14.0	

*P<0.05, **P<0.01; ***P<0.001; blank cells: non significant; grey cells: maize cultivation.

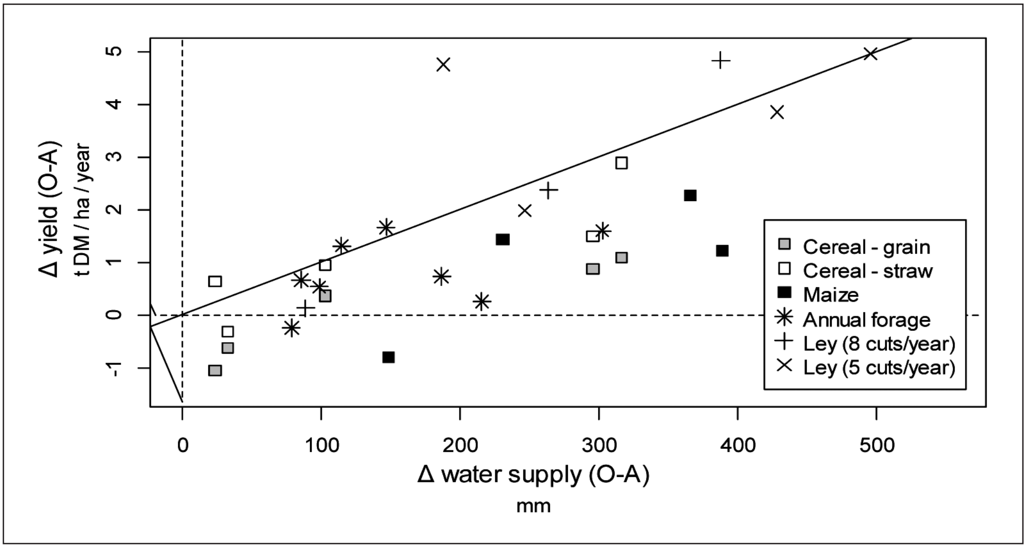

Fig. 1. Response of fodders DM yield to water supply (2010-2013).

Table 2 shows high differences among fodders mineral concentration. N- and K-content of grass-legumes mixtures (annual forage and leys) were much higher than those of cereal and maize. These results confirm the role of legumes in improving the nutritive value of forage. The effect of water availability was significant in a limited number of situations. As already shown (e.g. Jensen *et al.,* 2010), additional water supply on O plots was accompanied by a dilution of N in the biomass. Due to legumes N-fixation, the N-content of annual forage and leys is twice that of maize, while the cereal grain content is intermediate. The K-content was largely enhanced with supplemental water, indicating the liberation of this element by soil. P was less influenced by water status than N and K, confirming the low mobility of this element.

Table 2. N, P and K content of fodders from 2010 to 2013 under the two water regimes (A, O)

	Year	Cereal - grain			Maize		Annual forage			Ley (8 cuts/y)			Ley (5 cuts/y)		
		A	O		A	O	A	O		A	O		A	O	
N-content (% DM)	2010	1.62	1.61		0.98	0.95	2.74	2.78		2.92	2.89		2.75	2.35	
	2011	1.82	1.65	*	1.15	0.99	2.98	2.88		2.76	2.63		2.16	1.80	***
	2012	1.58	1.54		0.92	0.83	3.75	3.36	***	2.46	2.43		2.73	2.94	*
	2013	1.63	1.60		1.03	0.97	2.75	2.88		2.44	2.54		2.41	2.26	*
P-content (% DM)	2010	0.42	0.44		0.17	0.18	0.33	0.36	**	0.37	0.39		0.35	0.38	*
	2011	0.36	0.41	*	0.19	0.20	0.37	0.38		0.40	0.43	*	0.37	0.39	
	2012	0.40	0.39		0.17	0.18	0.40	0.41		0.47	0.48	**	0.38	0.36	
	2013	0.41	0.40		0.23	0.24	0.37	0.36		0.46	0.46		0.34	0.33	
K-content (% DM)	2010	0.55	0.59	*	0.57	0.61	2.83	3.08	**	2.77	3.20	***	2.62	3.02	*
	2011	0.43	0.45	*	0.83	0.79	3.11	3.37	**	3.20	3.58	**	3.03	3.44	*
	2012	0.48	0.48		0.80	0.88	3.40	3.74	**	3.46	3.64		3.22	3.18	
	2013	0.55	0.53		0.85	0.94	3.50	3.43		3.58	3.46		2.91	2.74	

*P<0.05, **P<0.01; ***P<0.001; blank cells: non significant.

IV – Conclusions

The forage strategies practiced on the Swiss lowland reacted diversely to the level of water availability. Silage maize cultivated in rotation with winter barley and alfalfa-ryegrass annual forage provided the largest DM yield and was less influenced by the water regime than leys. Therefore, despite their lowest mineral content, annual crops have to be considered in regions prone to drought. The results clearly showed the sensitivity of grassland to water conditions. During dry years, additional water amounts of 300 to 500 mm have been applied in order to adapt soil tension to plant need. Without water limitation, leys production meets perfectly the objectives of forage autonomy in herding systems. However, the study pointed out the gradual yield loss of leys over the years. In conclusion, the development of perennial grass-legumes mixtures has to be continued in consideration of the climate change.

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