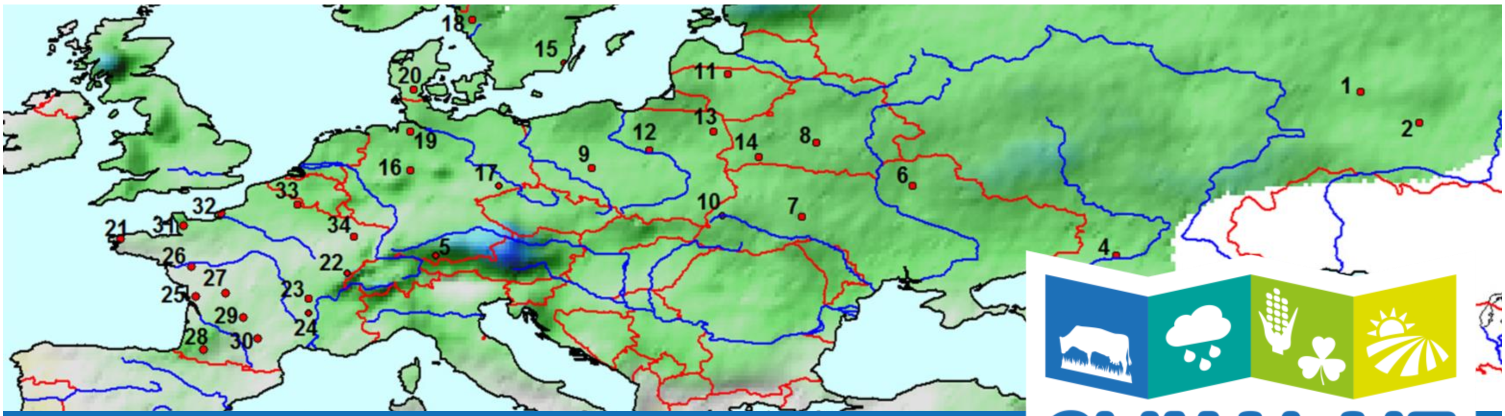

CLIMALAIT

Modelled consequences of climate change on fodder production in selected milk-exporting countries.

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Abstract

The French dairy professional organization, CNIEL, currently finances a study named Climalait with an international focus exploring the possible evolution of the climatic conditions in areas active on the world dairy market. This prospective study is based on the WorldClim data from the CNRM (RCP 8.5) and the LGP (Length Growing Period) proposed by the FAO. Several agricultural and climatic indicators were calculated for these areas, both on past periods (1950-2000) and for the future (2041-2060). The evolution of the LGP is estimated by a statistical model based on WorldClim data. Evolutions of the various indicators and of the LGP put areas with similar potential climatic futures regarding forage production to the fore. Some of these regions will gain real competitive assets.

Keywords: climate change, fodders, milk production, WorldClim data, LGP

Introduction

Climate change already impacts fodder systems of dairy farms (Noury et al., 2013) in France. Farmers noticed that they could turn out to grass sooner but that summer droughts were longer. Sometimes local difficulties emerge to achieve fodder stocks, irrigation being hence necessary to secure the forage balance of the farm. The French dairy chain represented by its professional organization, CNIEL, financed a study on several axes. One of them studies ways to adapt production systems to climate change as they may be proposed by farmers themselves in 30 zones distributed on the domestic territory. The second axis explores climatic conditions of fodder production in other milk producing countries as well as in a few French study areas from the first axis. Milk producing countries targeted in this study are those now acting as main exporters on the world market, or with the potential to do it in the near future (FAO et al., 2014): North America (various western or north-eastern areas such as Great Lakes, Saint Laurent and Texas), Rio de la Plata basin (Argentina, South Brazil, Paraguay, Uruguay), Oceania (South-Eastern Australia, New Zealand) and Europe (several areas in France, Germany, Scandinavia, Poland, Ukraine, Belarus and Russia). Only results for European countries are presented here.

Materials and methods

Using statistical data of territorial cow distribution (Robinson *et al*., 2014), 61 areas were identified in 17 countries. In this study RCP 8.5 was the climatic data used proposed by the WorldClim organization (Fick and Hijmans, 2017), issued by the CNRM's climate simulator. The 10' resolution (one point every 18.5 km – 550,000 points) on the 1950-2000 (historical data) and 2041-2060 periods of time were selected. Variables are all period averages. It deals with 12 monthly values of minimal temperature, maximal temperature, precipitations (but not PET) and 19 indicators based on those 36 variables. LGP data available on the FAO site were used in order to estimate one of the possible impacts of climate change on fodder cultures. Length of growing period (LGP) is defined (FAO, 1996) as the year period when average temperatures are higher than or equal to 5°C and precipitations plus moisture stored in the soil exceed half the potential evapotranspiration ($P > 0.5$ PET).

As achieved by Phelan *et al*. (2016) on the GSL (Grazing Season Length), a statistical model of LGP estimation was built on the basis of historical data from WorldClim base. This model was then applied on climatic data between 2041 and 2060. The difference between LGP estimated for the future and LGP estimated for the past with this model (Figure 1) is used as a synthetic indicator for evolution of climate conditions as experienced by grass.

In order to consolidate this major indicator, five others were calculated: the 4 season-evolution of the P-PET water balance, and the date foreseen for possible grass turnout (grass turnout = day when the sum of daily average temperatures since the 1st of February reaches a total of 300°C) Sooner turnout to grass corresponding to LGP increase may mean a true extension of the possible period of grass use. Monthly PET were estimated from the temperature (Allen *et al.*, 1998), as the average of PET value obtained by the Thornthwaite formula and the one obtained by the Hargreaves formula: this solution was validated after comparisons to Penmann-Monteith PET available on French sites (Alkaeed *et al.*, 2006). Water balance evolution (P-PET) gives us information on the evolution of water intake conditions of summer fodder plants such as maize. Site classification was achieved using Principal Component Analysis and cluster analysis.

Results and discussion

WorldClim data analysis showed strong correlations among variables. Indeed, a multiple linear regression type LASSO (Least Absolute Shrinkage and Selection Operator) - very restrictive on variables' selection (Tibshirani, 1996) - was used. For the Northern hemisphere the following data are part of the model: March maximal temperatures, February and October precipitations, precipitations of the driest quarter, temperature and precipitations seasonal distributions. In Europe (34 sites among 61 observed), the classification per evolution similarity brings out 5 classes (Figure 2). The A class countries (i.e. Russian areas) are characterized by a high raising LGP with possible earlier grass turnout. Autumn growth may be more sustained than summer growth because it appears that the summer water balance declines, which is also not favourable to maize crops without irrigation. For the C class countries (i.e. Poland, Belarus, Ukraine) the situation appears to be very profitable above all in the Western parts, with a possible extension of growth period (LGP) and a better water balance (despite a strong PET increase), which should be good for maize. There is already a precipitation pattern with summer maximum in those areas. The findings for the D class (Germany, South Scandinavia) is similar to A class as far as climate evolutions are concerned but represents a particular type due to less continental features (i.e. more precipitations and less temperature gaps). There are three sub-classes in E class (i.e. French areas). The first one corresponds to Western Brittany with few temperature evolutions but a declining summer water balance. The second one deals with mountain zones (Jura and Massif Central) where growth periods may increase, particularly with earlier spring but a worse water situation in late spring and summer. Situations seem to be harder for South Western sites in the third sub-class due to low raising LGP and decreasing water balances. However, it appears slightly better North of Seine. Finally, the situation in Bavaria appears quite peculiar (B class) with 4 indicators clearly evolving positively both for grass and maize crops. WorldClim data allow to outline trends on a rather thin geographical scale but not to study inter-annual climatic variability, one of the most sensitive aspects of the effects of climate changes on agriculture and livestock particularly.

Conclusion

According to RCP 8.5 and the CNRM climatic model, large lowlands of Central Europe, from Rhine to Dniepr basin, seem to benefit from climate change with better prospects for grass and silage maize cultivation and growth. As a result a synergy exists between milk production development dynamics and climate evolution. With summer water balance getting worse, evolution seems to be less favourable in Western and South-Western France.

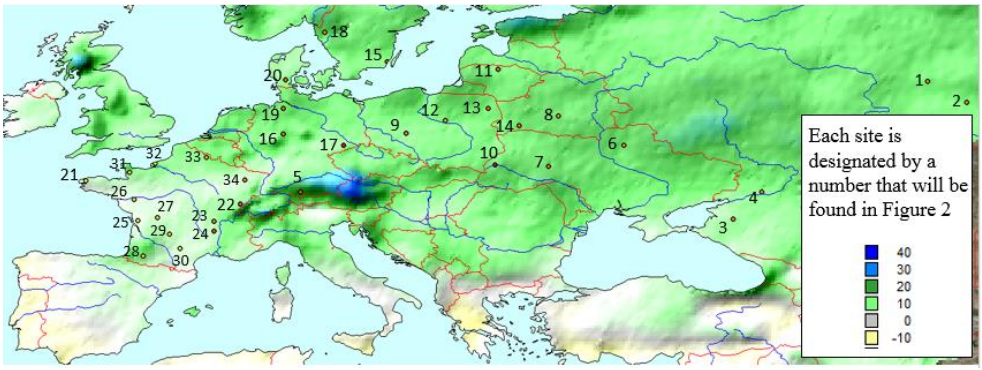
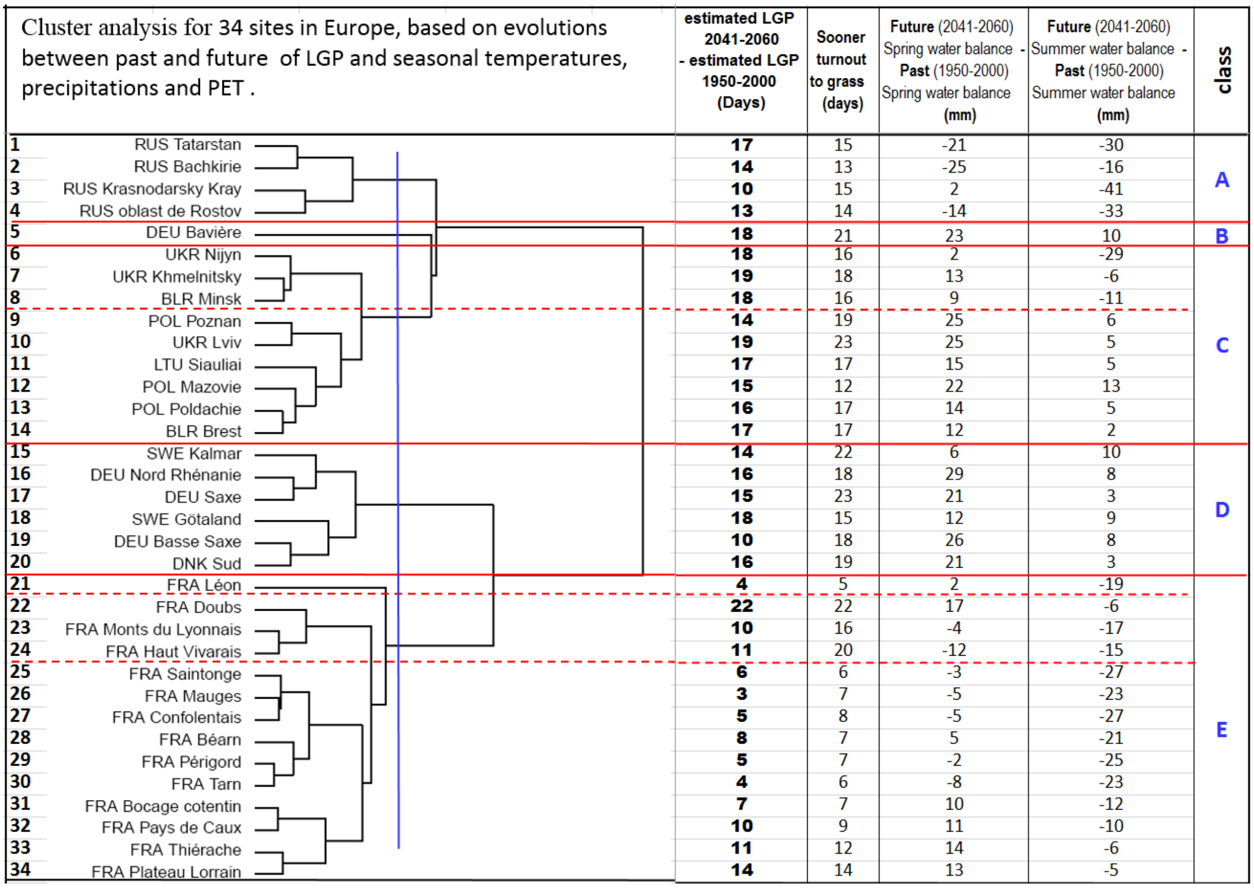


Figure 1. Projected increase in length of growing period (LGP) (number of days in period 2041-2060 – number of days in period 1950-2000).



Cluster analysis for 34 sites in Europe, based on evolutions between past and future of LGP and seasonal temperatures, precipitations and PET .		estimated LGP 2041-2060 - estimated LGP 1950-2000 (Days)	Sooner turnout to grass (days)	Future (2041-2060) Spring water balance - Past (1950-2000) Spring water balance (mm)	Future (2041-2060) Summer water balance - Past (1950-2000) Summer water balance (mm)	class
1	RUS Tatarstan	**17**	15	-21	-30	A
2	RUS Bachkirie	**14**	13	-25	-16	
3	RUS Krasnodarsky Kray	**10**	15	2	-41	
4	RUS oblast de Rostov	**13**	14	-14	-33	
5	DEU Bavière	**18**	21	23	10	B
6	UKR Nijyn	**18**	16	2	-29	C
7	UKR Khmelnitsky	**19**	18	13	-6	
8	BLR Minsk	**18**	16	9	-11	
9	POL Poznan	**14**	19	25	6	
10	UKR Lviv	**19**	23	25	5	
11	LTU Siauliai	**17**	17	15	5	
12	POL Mazovie	**15**	12	22	13	
13	POL Poldachie	**16**	17	14	5	
14	BLR Brest	**17**	17	12	2	
15	SWE Kalmar	**14**	22	6	10	D
16	DEU Nord Rhénanie	**16**	18	29	8	
17	DEU Saxe	**15**	23	21	3	
18	SWE Götaland	**18**	15	12	9	
19	DEU Basse Saxe	**10**	18	26	8	
20	DNK Sud	**16**	19	21	3	
21	FRA Léon	**4**	5	2	-19	E
22	FRA Doubs	**22**	22	17	-6	
23	FRA Monts du Lyonnais	**10**	16	-4	-17	
24	FRA Haut Vivarais	**11**	20	-12	-15	
25	FRA Saintonge	**6**	6	-3	-27	
26	FRA Mauges	**3**	7	-5	-23	
27	FRA Confolentais	**5**	8	-5	-27	
28	FRA Béarn	**8**	7	5	-21	
29	FRA Périgord	**5**	7	-2	-25	
30	FRA Tarn	**4**	6	-8	-23	
31	FRA Bocage cotentin	**7**	7	10	-12	
32	FRA Pays de Caux	**10**	9	11	-10	
33	FRA Thiérache	**11**	12	14	-6	
34	FRA Plateau Lorrain	**14**	14	13	-5	

Figure 2. Evolution of the LGP and 3 other complementary indicators by class (sites evolving in the same way)

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