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What will be the consequences of climate change on soft wheat in Normandy (France) in 2050-2100 ? Prospective impact study based on ALADIN-Climate model

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1. Introduction

France is the fifth largest producer worldwide of soft wheat. Every year over 35 million tons of wheat are harvested (average 2011-2017, data from France AgriMer) on the territory. Hence, the cereal sector occupies a key place in the French agricultural economy. Normandy makes a significant contribution to this outcome with 3,6 million tons. Most of the production is exported to Maghreb and China via ports located in Rouen and Caen. However, because of its high dependence on atmospheric conditions, wheat production is vulnerable to climate change. Since the mid-1990s, a stagnation of yield has already been observed. According to the agronomists, climate change is responsible for that : Water deficit during stem elongation and scalding days during grain filling (Gate, 2009 ; Brisson *et al.*, 2010).

2. Climate context : observation and projection

Normandy climate is favourable to wheat production. Proximity to the English Channel helps to mitigate severe frosts and summer heat waves. However, risk of water deficits in spring is not excluded, especially where the soil is thinner. But climate is changing. The average temperature has already known a +0.8°C increase between the 1951-1980 and 1981-2010 climate normal (fig. 2). It is going on, since the temperature of the last nine years is 0.5°C above of 1981-2010's normal. On the other hand, there is no significant trend concerning cumulative rainfall.

Fig.3 Evolution of scalding days (25°C) in May, June and July by 2100 in Normandy

The intent of this study is to present what would be the climatic conditions for soft wheat in 2050 and 2100 and to compare them with the reference period (1976-2005). The climatic data is extracted from ALADIN-Climate (data from CNRM-2014 with a spatial resolution of 8x8 km) concerning three RCP scenarios of IPCC, available on the “*Drias Les futurs du climat*” website. Without any reduction of global greenhouse gas emissions, temperature could rise by as much as +3.6°C (fig.2). The number of hot days over May, June and July would be multiplied by four (fig.3). At the same time, cumulative rainfall would decrease by -13% in spring and -30% in summer. Given the stagnation in yields already observed, this is alarming.

3. Method : bioclimatic approach

4. Results

Harvest on 02 August 2019 (picture : Beauvais, 2019)

What will be the consequences ?

Consequently, there would be a shorter overlap between the end of the crop cycle and the summer period, usually characterized by heat waves and water stress events which are expected to occur more often. Thus, high temperature triggered scalding wouldn't be observed as much as expected and the cumulated water limitation would be also lower (fig.5.A,B,C,D). The impact on grain filling would be no heavier than at present. However, because of this precocity, emerging consequences might be expected regarding deleterious effects of lower temperatures during meiosis (tab.1), and decrease of solar radiation at the onset of stem elongation (fig.5.G,H). Mild winters would also reduce the number of vernalization days (not providing the required amount of cold days during tillering ; fig.5.E,F). In the end, given the greater occurrence of these new hazards, the fertility of the ears, and the growth and flowering of the wheat could be impacted.

Tab.1 Evolution of the occurrence of the number of years with at least one day of low temperature (Tn< 4°C) during meiosis in Caen and Evreux

Scenario	Caen	Evreux
1976-2005		
SAFRAN observation	03/30	03/30
Historical scenario	05/30	06/30
2021-2050		
RCP 2.6 scenario	04/30	10/30
RCP 4.5 scenario	06/30	10/30
RCP 8.5 scenario	08/30	11/30
2071-2100		
RCP 2.6 scenario	09/30	12/30
RCP 4.5 scenario	07/30	12/30
RCP 8.5 scenario	09/30	11/30

Phenological observations (Beauvais, 2019)

A few references :
- Beauvais F., Cantat O., Madeline P., Le Gouée P., Brunel-Muguët S., Medjkane M., 2019. Quelles conséquences du changement climatique sur le blé tendre en Normandie aux horizons 2050 et 2100 ? Étude d'impact prospective à partir du modèle ALADIN-Climate. *Climatologie*, mis à jour le : 09/04/2020. URL : <http://odel.revues.inist.fr/climatologie/index.php?id=1414>, <https://doi.org/10.4267/climatologie.1414> ;
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Phenology is simulated using the concept of degree days (base 0°C) with an associated 11h photoperiodic criterion for the beginning of the stem elongation. The occurrence of climatic hazards is linked to the phenological stages of the plant (fig. 4): water deficit (entire cycle), thermal exhaustion (scalding day : 25°C), vernalization (between 3°C – 10°C), low temperatures (< 4°C during meiosis) and radiation deficit (stem elongation ; Gate, 1995).

Indeed, those hazards are able to generate consequences to the agricultural yield. Studying the effect of climate on crops by taking into account phenology (Holzkämper et al., 2013) and its interannual variability is more precise than agroclimatic indicators for invariant dates (Caubel et al., 2015). The elements presented are a selection of the results published in Beauvais *et al.*, 2019.

Phenology anticipation : harvest in early July ?

In the reference period the physiological maturity of wheat occurs at the end of July, which corresponds to harvests in early August. In the context of a pronounced climate change, along with unchanged sowing dates by 2050 and 2100, the increase in temperatures would lead to shorten the crop cycle, and hence to a date shift in the plant phenology. In the short term, physiological maturity would show up in mid-July for the three scenarios, which corresponds to a two-weeks cycle reduction. In the long term, with the RCP 4.5 scenario, maturity would occur at the beginning of July and at the end of June for the warmest scenario. So in 2100 the wheat harvest could take place at the beginning of July.

Fig.5 Evolution of phenoclimatic indicators by 2050 and 2100 in Caen and Evreux for three RCP scenarios

Fig.6 The spatiale variability of temperature : example North of Caen (From 14:27 to 15: 23 the 24 June, 2018)