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Presented by:

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Theme

Contribution of the Geomatics in the caracterization of the climate change impact on development of wheat diseases.

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First of all, I thank God who gave me courage, strength, patience and will to put an end to this work.

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Résumé

Le blé est la principale production céréalière, la plus cultivée et la plus consommée dans le monde. Il est sensible aux attaques de plusieurs maladies qui peuvent diminuer son rendement. En Algérie, la superficie réservée aux céréales au cours des 20 dernières années est en moyenne de 2,7 millions d'hectares, dont 1,4 millions d'hectares sont occupés par le blé dur. La production stagne sur une longue période. Le secteur céréalier occupe une place très importante dans l'économie algérienne car, l'Algérie fait partie du groupe des plus grands importateurs de blé dans le monde, où elle est classée à la sixième place. L'objectif de notre travail est de fournir la théorie de base de la géomatique pour caractériser l'impact du changement climatique sur le développement des maladies du blé. Nous avons démontré l'utilité et l'importance de la télédétection dans la surveillance et la modélisation des maladies fongiques du blé en utilisant des images satellites. Le climat joue un rôle clé dans le développement du blé et s'oppose parfois à sa croissance et à son développement, car les facteurs climatiques peuvent agir directement sur la physiologie de la plante. Les indices de végétation permettent de relier les valeurs de réflectance aux caractéristiques physico-chimiques des plantes. Dans le cas de la détection de colorations anormales des plantes, les indices de végétation sont utilisés pour estimer la biomasse foliaire et la teneur en chlorophylle, en distinguant ceux calculés à partir de données multispectrales et hyperspectrales. La plupart des indices de végétation sont obtenus par des combinaisons arithmétiques de bandes spectrales du visible et du proche infrarouge.
Mots clés : Blé, télédétection, changement climatique, agriculture de précision, indices de végétation.

Abstract

Wheat is the main cereal production, the most cultivated and the most consumed in the world. It is susceptible to attack by several diseases that can decrease its yield. In Algeria, the area reserved for cereals over the last 20 years has averaged 2.7 million hectares, of which 1.4 million hectares are occupied by durum wheat. Production is stagnating over a long period of time. The cereals sector occupies a very important place in the Algerian economy because, Algeria belongs to the group of the largest importers of wheat in the world, where it is ranked in sixth place. The aim of our work is to provide the basic theory of the Geomatics to characterize of the climate change impact on development of wheat diseases. Herein, we demonstrated the usefulness and importance of remote sensing in monitoring and modeling of fungal diseases of wheat using satellite images. Climate plays a key role in wheat development and sometimes is opposed to its growth and development, because climatic factors can act directly on the physiology of the plant. Vegetation indices allow to link reflectance values to physicochemical characteristics of plants. In the case of detecting abnormal plant colorations, vegetation indices are used to estimate leaf biomass and chlorophyll content, distinguishing between those calculated from multispectral and hyperspectral data. Most vegetation indices are obtained by arithmetic combinations of arithmetic combinations of visible and near-infrared spectral bands.
Keywords: Wheat, remote sensing, climate change, precision agriculture, vegetation indices.

ملخص

القمح هو إنتاج الحبوب الرئيسي والأكثر زراعة والأكثر استهلاكًا في العالم. إنه عرضة للهجوم من قبل العديد من الأمراض التي يمكن أن تقلل من إنتاجها. في الجزائر، بلغ متوسط المساحة المخصصة للحبوب على مدى السنوات العشرين الماضية 2.7 مليون هكتار ، منها 1.4 مليون هكتار مشغولة بالقمح الصلب. الإنتاج راكد على مدى فترة طويلة من الزمن. يحتل قطاع الحبوب مكانة بالغة الأهمية في الاقتصاد الجزائري لأن الجزائر تنتمي إلى مجموعة أكبر مستوردي القمح في العالم حيث تحتل المرتبة السادسة. الهدف من عملنا هو تقديم النظرية الأساسية للجيوماتكس لوصف تأثير تغير المناخ على تطور أمراض القمح. هنا أوضحنا فائدة وأهمية الاستشعار عن بعد في رصد ونمذجة الأمراض الفطرية للقمح باستخدام صور الأقمار الصناعية. يلعب المناخ دورًا رئيسيًا في تطوير القمح وأحيانًا يعارض نموه وتطوره ، لأن العوامل المناخية يمكن أن تؤثر بشكل مباشر على فسيولوجيا النبات. تسمح مؤشرات الغطاء النباتي بربط قيم الانعكاس بالخصائص الفيزيائية والكيميائية للنباتات. في حالة اكتشاف الألوان غير الطبيعية للنبات ، تُستخدم مؤشرات الغطاء النباتي لتقدير الكتلة الحيوية للأوراق ومحتوى الكلوروفيل ، مع التمييز بين تلك المحسوبة من البيانات متعددة الأطياف وفائقة الأطياف. يتم الحصول على معظم مؤشرات الغطاء النباتي من خلال التوليفات الحسابية للتركيبات الحسابية للنطاقات الطيفية المرئية والقريبة من الأشعة تحت الحمراء.

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Liste des abréviations

Abréviation	Signification
FAO	Food and Agriculture Organization.
MADR	Ministère de l'Agriculture et du Développement Rural.
IPCC	Intergovernmental Panel on Climate Change
CC	Climate Change.
GHGs	Greenhouse Gases.
UAA	Utilized Agricultural Area.
RCPs	Representative Concentration Pathways.
SMLR	Stepwise Multiple Regression.
ANN	Artificial Neural Network.
CPMs	Climate projection models
MNT	Terrain Numerical Model
FGLS	feasible generalized least square
ABM	Agronomic best management

Introduction

Among human activities, agriculture is undoubtedly among the most directly influenced by Climate Change (CC). Therefore it will impact the biotechnical component of agricultural production processes .CC impacts negatively the agricultural activities in a multifaceted way; it impacts farm household's incomes, farm biophysical compounds and also the collective dynamics of the farming territories, hence it contributes to increasing the vulnerability of poverty. Agriculture is a particularly CC sensitive sector, which can also contribute to its expansion. Organic and inorganic material provided as inputs or outputs in the management of agricultural systems are typically broken down through bacterial processes, releasing significant amounts of Greenhouse Gases (GHGs) namely CO2, CH4, and N2O to the atmosphere (**LAMINE *et al*., 2018, 2019, 2020, 2022 ; BACHARI *et al*., 2021 ; DENG *et al*., 2019a, 2019b ; EVANS *et al*., 2018 ; DIKE *et al*., 2018 ; PETROPOULOS *et al*., 2016).**

The agricultural sector is the largest contributor to global anthropogenic non-CO2 GHGs, accounting for 24 % of global emissions in 2010. However, some conservation agricultural practices may also contribute to the reduction of these gases in the atmosphere (Machane, 2010). Referring to the ancient or recent texts, the reputation of North Africa as “granary of Rome” seemed well established .There are even those who have named the region of Sétifois in Algeria by this term, given its durum wheat yield potential.

Unfortunately, nowadays, this term becomes feeling awkward. Cereal farming is an important component of Algerian agricultural and food economies, as Algeria belongs to the largest group of wheat importers in the world, where it ranks sixth with an average of 5 - 6 million tons in 1990 -92 and 2000-2003 respectively (FAO, 2005). In fact, cereals are located mainly in eastern Algeria, Where Sétifois region holds 42% average of the Utilized Agricultural Area (UAA) and climate, especially rainfall and temperatures are the predominant factors that strongly influence crops (Feliachi, 2000). Locally, the majority of agricultural land is cultivated under rainfed conditions, where annual rainfall is insufficient and unpredictable from one year to another, as well as extreme seasonal temperatures are opposing the development of crops. Several climate models forecast that Algeria will experience decreased rainfall and increased temperatures; this will have a direct impact on agricultural productivity and food security.

In this context, this work is carried out; primarily to draw up a starting position of the state of the cereal production in Sétifois region by illustrating the geographic potential in terms of areas and yields. Second step is to study the annual rainfall and the maximum and minimum temperature; starting with studying the reference period 1960-90 and then passing to 2070 horizon. Among four Representative Concentration Pathways (RCPs) adopted by the IPCC in its last report in 2014, two RCPs were adopted in this paper namely: RCP 2.6 as an optimistic scenario and RCP 8.5 as a pessimistic one. Some statistical predictive methods such as the Stepwise Multiple Regression (SMLR) and the Artificial Neural Network (ANN) will be validated and then performed for expecting cereal yields in 2070.

We were doing the researchs, it was the main objective of her to facilitate the identification of cereal diseases (wheat), and we were knew the effects of climate change on the diseases wheat, and the means of control. it was that all through methods are statistical, analytical, and descriptive methods, they make it possible to materialise agro-climatic regionalization in different forms.

Also, to know the geomatic methods for forecasting diseases cereal, there're methods we studied are climate projection models, monitoring the environment through remote sensing, and modelling and impact of climate parameters on wheat production, and also knowing the specral indices used in the diagnosis of cereal diseases...etc

CHAPTER 01

Wheat Generalities

I.1. Origin and history of wheat

Wheat is of Asian origin, precisely from China, it was grown in considerable expansion 4000 years ago BC. It was the main crop in ancient Egypt and Palestine **(FAO, 2006).**

Since the birth of agriculture, wheat has been the basis of human food **(RUEL., 2006)**. It is a species known since ancient times, from which it constitutes the food base of the populations of the globe **(Yves and de Buyer., 2000).**

Durum wheat comes from the territories of Turkey, Syria, Iraq and Iran **(Feldman, 2001)**. The term wheat probably comes from the Gallic blato (originally from the old French blaie, blee, blaier, blaver, hence the verb emblaver, which means seeding wheat) and refers to the grains that ground, provide flour, for porridge (polenta), pancakes or bread. Various species are found under the name of wheat: the genus Triticum: modern wheat (wheat), barley (Hordeum) and rye (Secale cereal), black wheat (buckwheat).

I.1.1. Definition

Wheat is an annual herbaceous, monocotyledon plant belonging to the genus Triticum.

The grass family or Poaceae. Today, two species dominate the world production, the common wheat (Triticum aestivum) and the durum wheat (Triticum durum).

I.1.2. Wheat in Algeria

In Algeria, the area reserved for cereals over the last 20 years has averaged 2.7 million hectares, of which 1.4 million hectares are occupied by durum wheat. Production is stagnating over a long period of time. Indeed, it is a mainly rainfed crop dependent on climate variability **(Baldy 1974).**

With a view to improving yields in order to achieve acceptable production, Algeria encouraged the use of the complementary irrigation technique, the latter would reduce the effects of climate aridity in areas with restricted rainfall cumulation, and fill the water deficit during critical periods. However, durum wheat production in Algeria did not reach, at best, 21 million quintals on a seeded and harvested area of 1,585,500 ha with an average yield of 12.8 q/ha in 1996 according to the information provided by the **M.A.D.R.**

I.1.2.1. Wheat Production and Area

Wheat production is easy because it adapts to varied soils and climates. The existence of varieties adapted to different environments and resistant to many diseases makes it possible to grow wheat in many countries. There are winter wheat and spring wheat, their planting and harvest times in the year are different. More than twenty thousand wheat varieties exist and hundreds of new ones are created each year **(ANNE-LAURE, 2007)**.

The cereals sector occupies a very important place in the Algerian economy because, Algeria belongs to the group of the largest importers of wheat in the world, where it is ranked in sixth place. Local production is very variable, as in the whole of the Maghreb, is due to research and improvement work little developed, adding the non stable climatic conditions especially the drought.

Table 1: Production and area under cultivation, and productivity of food grain in Ethiopia

Year	Cultivated land (millions of hectares)	Production (millions of quintals)	Yield (quintals/ hectare)	Growth rate (percentages)		
				Land	Production	Yield
2003–2004	8.7	103.6	11.9			
2004–2005	9.8	119.1	12.2	12.6	15	2.5
2005–2006	10.2	133.8	13.1	4.1	12.3	7.4
2006–2007	10.5	155	14.8	2.9	15.8	13
2007–2008	11	161.2	14.7	4.8	4	–0.7
2008–2009	11.2	171.1	15.3	1.8	6.1	4.1
2009–2010	11.5	180.8	15.7	2.7	5.7	2.6

Based on CSA (2006, 2007, and 2008)

I.1.2.2 Importance of durum wheat in Algeria

Winter cereals, partly durum wheat, remain the staple food of Algerian diets and are strategically important in human nutrition and animal feed and therefore occupy a prominent place in agriculture Algerian **(Boulai et al. 2007)**.

In Algeria, durum wheat is consumed in several forms, mainly couscous, pasta, bread and frik **(Anonyme, 2003) II**.

Economic importance is assessed through three main parameters: Production, consumption and imports **(Anonymous, 1999)**.

Indeed, cereals and their derivatives are the backbone of the Algerian food system, 54% of energy intake and 62% of daily protein intake come from these products and wheat accounts for 88% of the cereals consumed **(Padilla and Oberti, 2000)**.

Algeria ranks first in the world in wheat consumption with over 200kg per head in 2003 **(Kellou R., 2008)**. According to the Algerian Ministry of Agriculture and Rural Development, Algeria plans to produce 55 million quintals of cereals in 2012.

I.2. Wheat diseases

The main objective of this chapter is to gather sufficient information to facilitate the identification of foliar diseases (fungal or hidden) that negatively affect cereal production in Algeria. We describe these diseases and also identify their stages of development in order to find appropriate solutions to eliminate them. Before it caused huge crop losses.

According to **Aouali and Douici-Khalfi (2009)**, cereal diseases can be grouped according to the symptoms they induce and the parts they affect. As a result, a distinction is made between:

- Diseases causing localized symptoms on foliage.

- Diseases causing root rot.

- Diseases causing symptoms on the ears.

I.2.1. Rust

Wheat and barley are affected by different types of rust. The three types of rust affecting wheat are brown rust, black rust and yellow rust **(Amrani 2013)**.

According to surveys conducted by **Sayoud et al (1996)**, the presence of rust occurs mainly in the highlands and plains of the Mittija. Rust types can be distinguished by uredospore characteristics, uredospore color and host plant types. **Zillinsky, 1983)**.

I.2.1.1. Yellow rust: (Puccinia striformis)

Easily spotted, it is a typical outbreak disease. On the leaves, yellow streaks appear along the veins in spring. They consist of pustules aligned with the blade (visible with a magnifying glass). At the end of the cycle, these pustules take on a black coloration. The disease is infrequent in the region and usually affects only the most sensitive varieties.

Figure 01: Yellow rust disease in wheat

a - Symptoms

The symptoms of Puccinia striiformis are yellow or orange spherical blisters arranged in strips along the veins of the leaves, hence the name of this species.

It can also develop on the underside of the leaves on the ears and kernels. **(Aouali and Douici-Khalfi, 2009; Ezzahiri, 2001; Jlibene, 2011)**.

b- The development of the disease

The life cycle of P. striiformi is limited to two stages, uredinal and telial (**EL jarroudi, 2005)**. Plants infected after cereal emergence or during the fall are rare.

According to Prescott in 1987, primary infection is caused by wind-borne spores. The spores are yellow or orange, almost spherical, spiny, of 28-34 um of diameter. The caudal leaves appear at the leaf blade and sheath in the form of dark brown filaments where they remain covered by the epidermis. **(Zilinsky, 1983**.

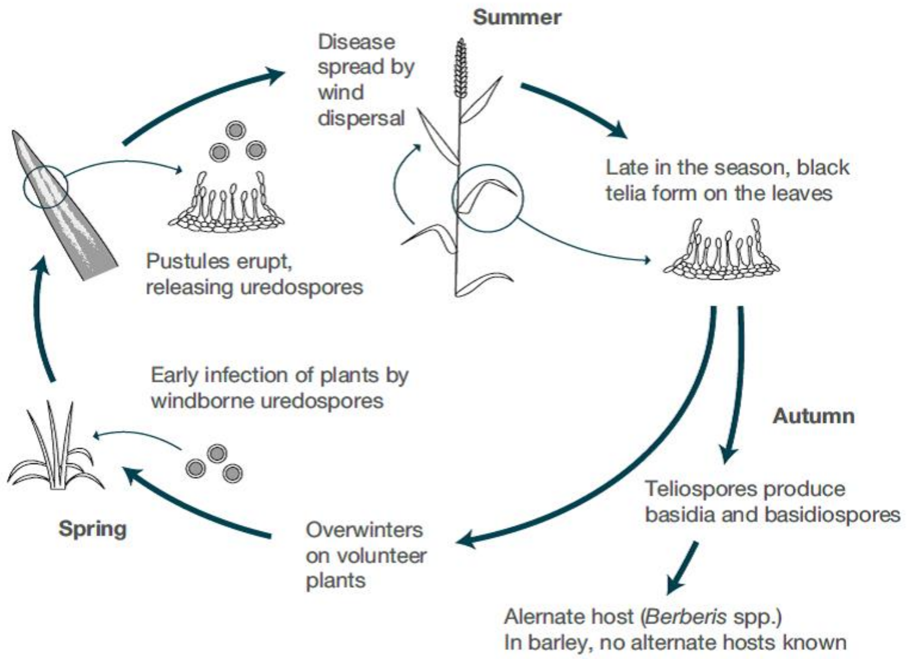


Figure 02: Yellow Rust Development Cycle

I.2.1.2. Brown rust :(Puccinia recondita)

Red to brown pustules appear randomly on the leaf blade, preferentially on the upper side. These pustules turn black at the end of the cycle. The finger turns brown at the passage on the blade, it is observed at the end of the run.

Figure 03: Brown Rust Diseases /syngenta 2021

a-Symptoms

Brown rust: Puccinia reconditaf.sp. tritici is responsible for the onset of this disease, as it consists of the formation of small round or oval blisters of orange color or brown (uredospores), on the upper side of leaves **(Sayoud et al., 1999; Ezzahiri, 2001(**. And sometimes under leaves. At the end of the season, these bulbs take a black teleutospores color, **(Aouali and Douici-Khalfi, 2009; Ezzahiri, 2001).**

b-Disease development

This disease develops in late winter, prefers high temperatures and humidity in spring, and develops rapidly this disease.

Primary infections are caused by uredospores**(Yahyaoui, 2003)**. The resulting infections appear early in the tallage stage, and subsequently constitute foci of infection characterized by the presence of pustules on the basal leaves.

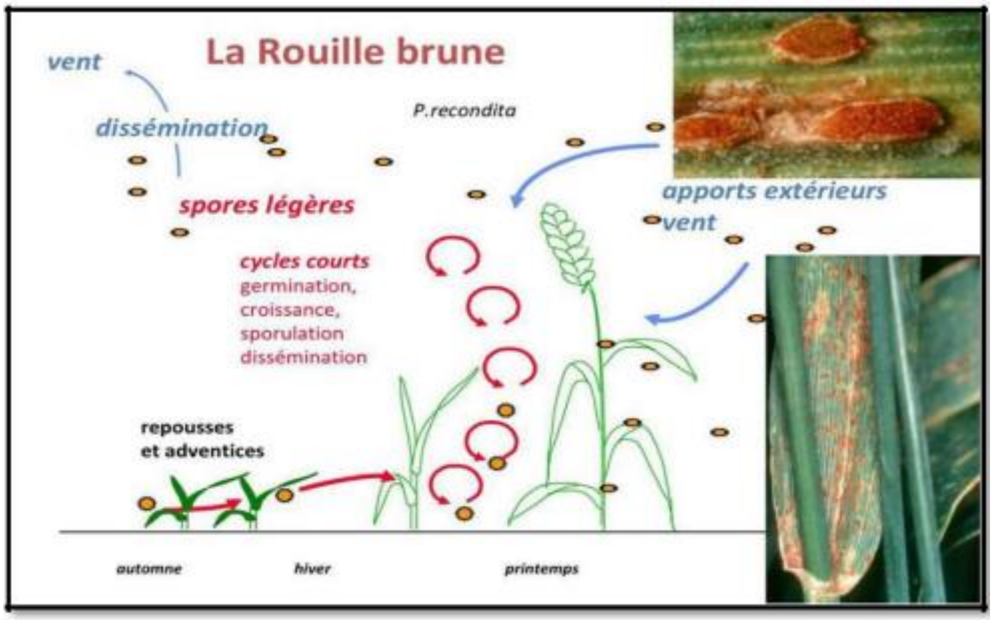


Figure 04: Brown rust development cycle (Abdi 2015).

I.2.1.3. Black rust :(<u> Puccinia graminisf.sp.tritici</u>)

<u>Puccinia graminis</u> is a species of basidiomycete fungi of the family Pucciniaceae. This species parasites the wheat in which it causes the «black rust» disease.

Figure 05: Black rust in wheat

a- Symptom

It is the rust that appears most late, usually at the creamy grain stage. It develops on the leaves, stems and even on the ears, forming elongated, brick-red to dark brown pustules **(Stackman et al 1962 and Martens et al 1979 in Benathemane 2005)**.

b- The development of the disease

In the case of wheat black rust, the uretdosporian and teleutosporin stages of this rust occur on the cereal, while the ecidian stage occurs on berberis (barbe vinette).

Primary infections are usually mild and are produced by uredospores sometimes carried far away by the wind, moisture (rain or Watering) and moderate temperatures are conducive to the development of the disease.

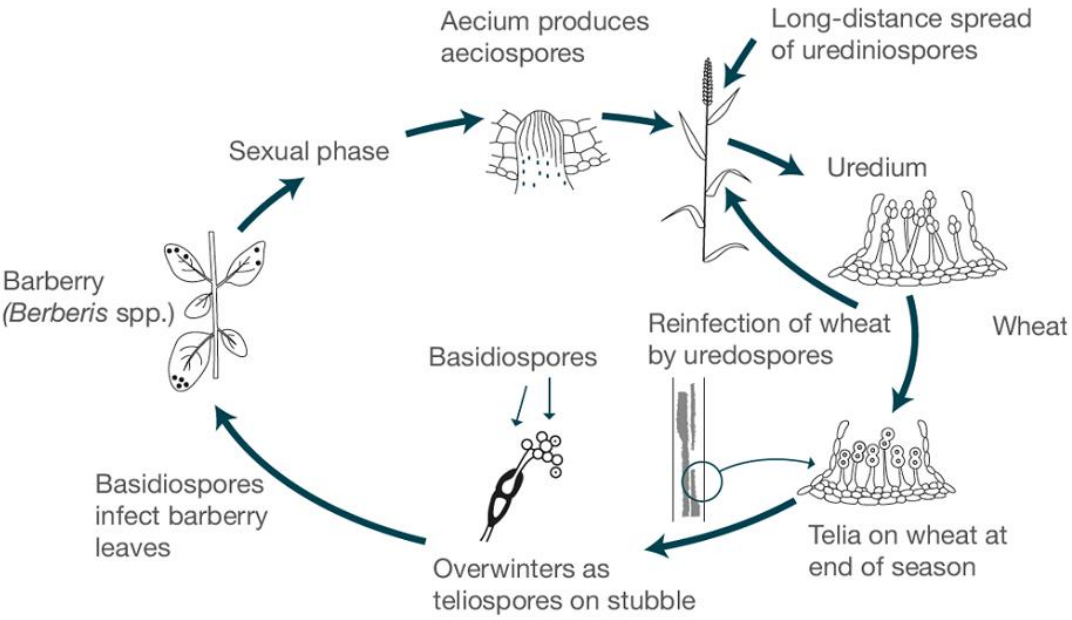


Figure 06: Stem (black) rust life cycle and risk to UK wheat

I.2.2. Fusarium head blight

It is a fungal disease. On the foot and stem, black streaks that extend in the form of a feather line following the veins. On the leaves, stains with large bottle green macula in the centre and on the cob blackish stains on the base of the glume and scalding, sometimes partial.

Fusarium head blight is a fungal disease found in a range of hosts, including wheat, barley, oats, corn, rye and grass **(Richard 2004; Wegulo et al. 2008 and Mathieu et al. 2012).**

a- Symptoms

The symptoms are very visible in the field because they manifest in premature bleaching of part or all of the ear. The first symptoms often appear in the centre of the ear from where they then progress up and down **(Zillinsky, 1983; Wegulo et al., 2008)**, the disease develops and sometimes spreads very quickly and can affect the entire ear.

b-Disease development

The fungus that causes the disease persists and breeds on infected plant residues, whether they are cereals, grasses, or other crops, grown or not, in and around the field. The Fusarium spores are deposited on the ears by the wind and splashes. Small cereals are susceptible to infection from flowering (epi appearance) to the semi-pasty stage, or later depending on the whims of the climate. The best conditions for infection are 48-72 hours of high humidity and 24-30°C temperatures.

The severity of fusarium head blight, which varies by field and year, depends on weather conditions, plant growth stage, and the presence of the pathogen. The earlier the infection occurs, the more severe the disease.

I.2.3. Septorioses

The disease progresses from the lower parts to the top of the plants. The symptoms are a function of the two main forms of septorioses: Septoria tritici and Septoriano dorum. Septoria tritici primarily attacks leaves. Spots are visible about 3 weeks after contamination. It can be observed as early as the fall, but especially from the stage of breeding.

Figure 07: Septoriose disease in the leaf

a- Symptoms

Symptoms of Septoriano dorum occur on the foliage and glumes, leaf sheaths and nodes. On the leaves, we can observe oval or lenticular brown spots, they can be surrounded by a chlorosis or a peripheral yellowing. When they are abundant, they meet and form large necrotic beaches.

Pycnids are lighter brown in colour than those caused by leaf septoriosis **(Ezzahiri 2001; Aouali and Douici-Khalfi 2009)**. Later, these pycnids turn dark grey.

Symptoms are small grey spots that will disappear and show brown coloration or scalding symptoms **(Ezzahiri 2001)**.

b-Disease development

The fungus that causes the disease persists and breeds on infected plant residues, whether they are cereals, grasses, or other crops, grown or not, in and around the field. The Fusarium spores are deposited on the ears by the wind and splashes. Small cereals are susceptible to infection from flowering (epi appearance) to the semi-pasty stage, or later depending on the whims of the climate.

The severity of fusarium head blight, which varies by field and year, depends on weather conditions, plant growth stage, and the presence of the pathogen. The earlier the infection occurs, the more severe the disease. If a cultivar is very sensitive, the inoculum is abundant at the time of flowering, and favorable atmospheric conditions are combined with these factors.

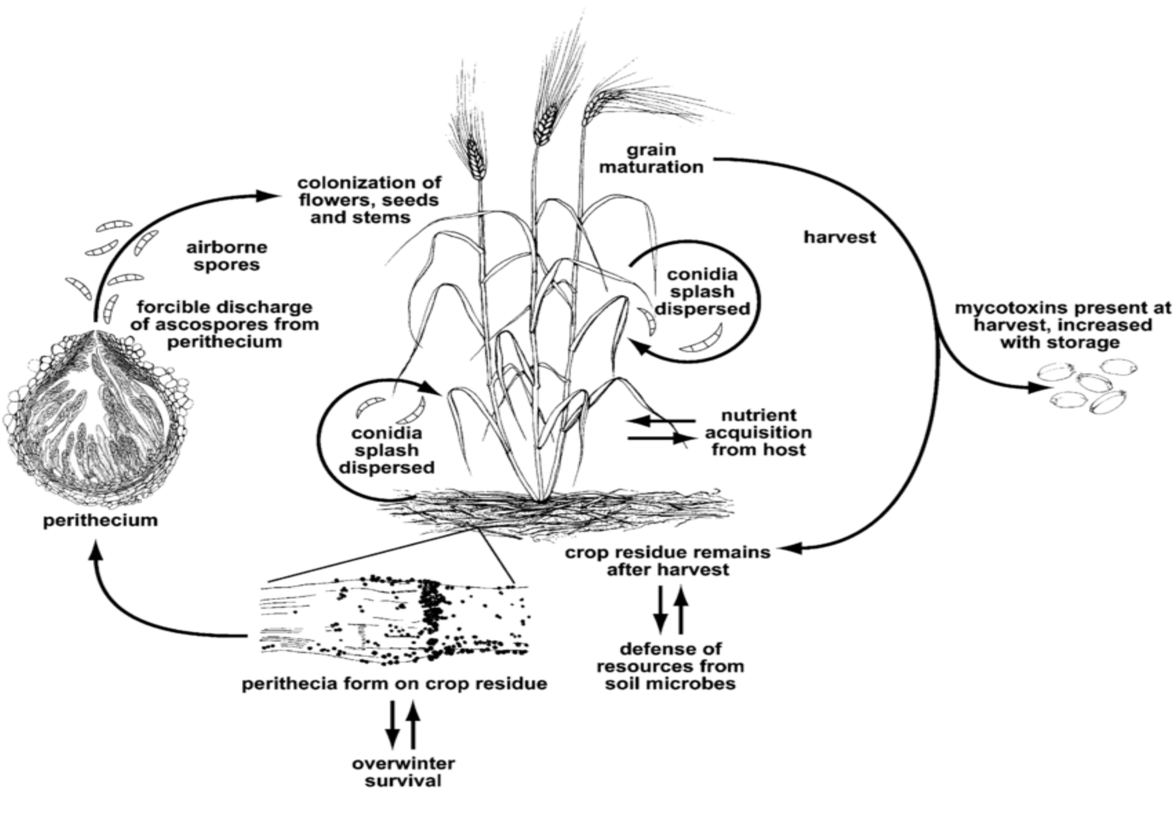


Figure 08: The life cycle of F. graminearum (sexual phase, G. zeae), causal agent of Fusarium head blight on wheat.

I.2.4. Powdery mildew

Powdery mildew is much less harmful than septoriose and rust. From 0 to 10 qx/ha wheat for attack on the ears. The frequency of this disease is low. Damage occurs when powdery mildew reaches the last leaf and ear, which affects the yield components (decrease in the number of kernels/ear and drop in the weight of a thousand kernels.

Figure 09: Powdery mildew in wheat

A-Symptoms

The first symptoms of Erysiphe graminisf.sp.tritici appear as whitish or pale grey down on the basal leaf blades and then develop on the upper leaf layers **(Ezzahiri, 2001; Anonymous, 2008; Aouali and Douici-Khalfi, 2009)**. In severe attack, spots also appear on the sheaths of the leaves and the glumes of the ears **(Ezzahiri 2001)**.

b- Disease development

Powdery mildew is caused by Blumeria graminis, an ascomycete belonging to the Erysiphales. It is an obligatory parasite specific to wheat **(Anonymous, 2018)**; in severe cases of infection the whole leaf becomes yellow and dies. Powdery mildew can cause severe burns to the upper leaves of susceptible varieties.

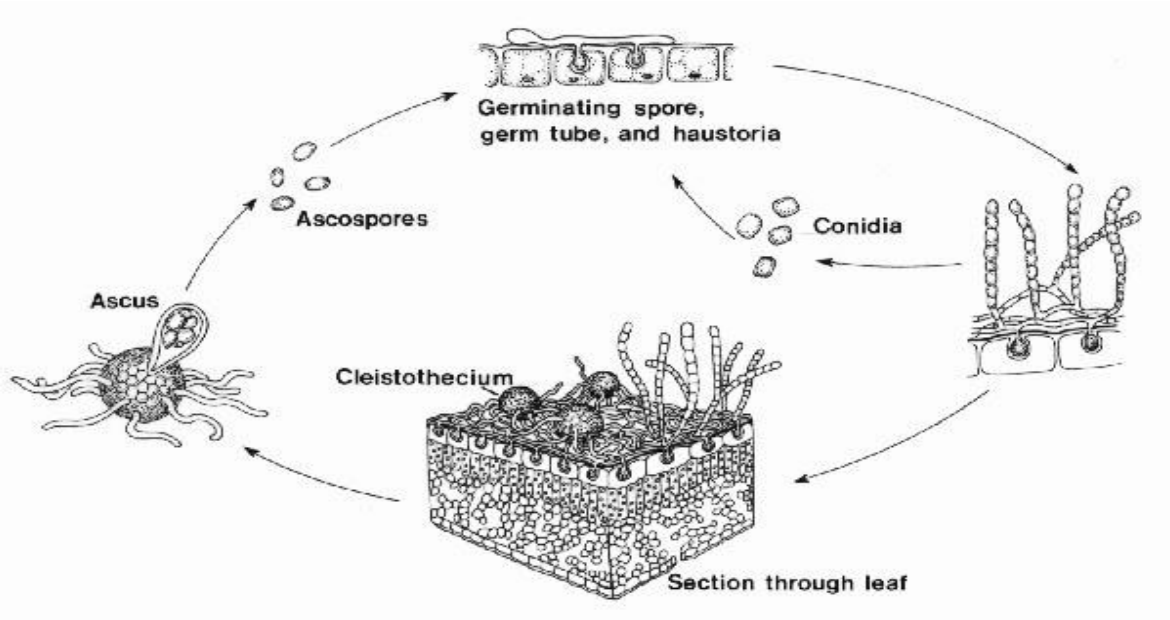


Figure 10: Generalized Life Cycle of Powdery Mildews

I.2.5. The Golden Spot: (Tan Spot)

Brown, round or oval spots with a chlorose halo appear as early as April if temperatures are between 12°C and 16°C and humidity is present.

They can extend to form a necrotic-chlorotic network. However, the presence of small dark brown necrosis in the centre of the chlorotic spots is a distinguishing feature of P. tritici-repentis lesions.

Figure 11: The haloed spot in the wheat leaf

a- The symptoms caused by this disease are

- Brown-black stain on the lower and upper sides of the leaves (the spots have a black spot in the centre, which is the point of infection).

- Presence of a chlorotic halo around the stains.

- Yellowish appearance of the leaves, which gradually decay from top to bottom and then fade.

b- The damage caused

- Once infected, plants quickly lose the leaf surface responsible for photosynthesis. Which is at the origin of the assimila synthesis for grain filling. Once the grain is affected the PMG decreases.

- In case of severe attack, the yield loss can be 50%. It is the second most common disease after the halo stain, even in the same regions. It had a significant impact in 2006, both on hard wheat and soft wheat. **(ANONYMOUS, 2007).**

c. The means of control

Control methods can be chemical, cultural or genetic, but it is preferable to integrate these different methods into a single program, which will be cheaper for the farmer **(Eyal, 1981).**

The control of cryptogamic diseases in wheat is intended to minimize and delay the development of diseases, to prevent them from reaching the upper leaves that contribute more than 50% to grain filling **(Lacroix, 2002).**

1. Cultural Control

To mitigate the severity of disease, researchers recommend the application of cropping practices and rotations with cleaning crops **(Shipton et al., 1971; King et al. 1983)** noted that for a long time, it has been recommended to burn crop residues. At present, this is no longer the case, as temperatures reached by this action may not be effective enough to remove all debris, leaving enough infected remains to maintain inoculum in another wheat crop **(Eyal 1981).**

2. Chemical Controls

Low molecular weight organic acids (propionic acid, acetic acid and formic acid) and their salts are most commonly used for grain preservation **(MAGAN et al., 2004).**

However, they have many disadvantages: their effectiveness depends on time; they are corrosive; acid treatments destroy the viability of the seed; and, above all, special care must be taken by the user to avoid inhalation.

Certain chemicals used to cope with degradation present a significant toxic risk: ethylene oxide, methyl bromide.

Formaldehyde has been used successfully to control the development of grain mould, but its use also poses many problems (smell, colour, loss of enzyme activity)

3. Physical Struggle

Physical methods have generally been applied in grain storage. Modified atmospheres and gamma irradiation should be mentioned. The lethal action of irradiation on living organisms results from chemical changes, even quantitatively minute ones, induced in their vital molecules **(MAGAN et al., 2004).**

I.3. The effects of climate change on wheat diseases

a- Impact: (Septoriose)

Septoriose grows in the main wheat growing territories in the European Union **(Fones and Gurr 2015)**. And can cause significant yield losses, also early development of septoriosis during the growing season with a significant impact on disease development and therefore on its impact on yields.

b- Influence of climatic factors

Septoriose develops mainly in humid climates and especially in maritime areas such as: northern France, England, Belgium and Germany **(Fones and Gurr, 2015)**.

Two climatic factors will mainly influence the spread of the disease: temperature and humidity **(Ben Mohamed et al., 2000)**.

Temperatures play an important role in the development of the disease **(Fones and Gurr, 2015).**

The optimum temperatures during the development cycle are between 18°C and 25°C **(Ben Mohamed et al., 2000)**. The optimum temperatures for infection are between 16°C and 21°C. Therefore to have a development of the septoriose there are necessary conditions:

- A very wet day, that is with precipitation greater than 10mm of rain or.

- Several consecutive wet days, that is, three consecutive days with at least 1mm of rain per day or.

- Total precipitation of more than 5mm on two consecutive days **(Verreet et al., 2000).**

The development of septoriose is therefore associated with an increase in precipitation and its frequency, dry conditions being unfavourable to its development although the relative humidity of the air has little influence (Savary et al., 2016; Verreet et al., 2000).

a- Impact: (Yellow rust)

Yellow rust is found in most wheat-growing countries **(Wellings 2011).**

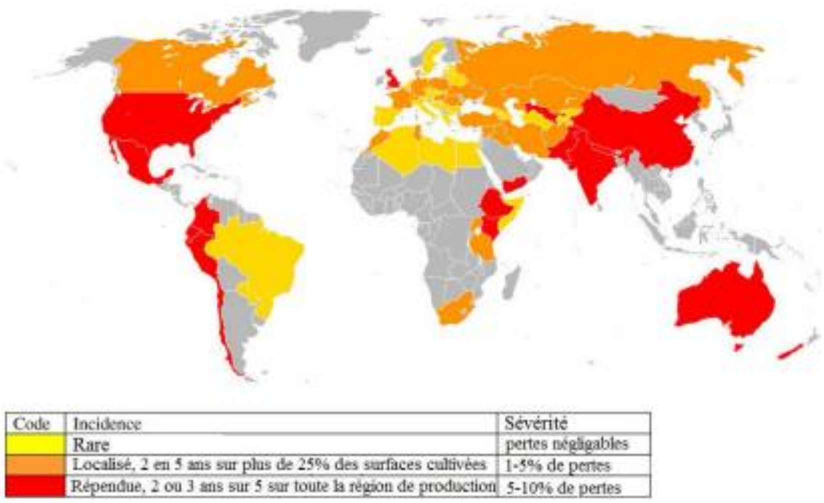


Figure 12: Geographic distribution of Yellow Rust (Wellings 2011)

b- Influence of climate factors

In the literature, yellow rust is widely reported as a pathogen developing in a cool environment. Other factors have a secondary importance in the spread of the disease, such as wind **(Savary et al., 2016).**

The optimum temperatures for rust development are between 9°C and 15°C. Beyond 15°C, the pathogen slowly slows down, according to **Savary et al. (2016),** the development of yellow rust is associated with average seasonal temperatures. **Bahri (2008)** reports that yellow rust is a pathogen that develops at cool temperatures ranging from -10°C to 25°C.

The rise in maximum temperatures above 25°C slows or stops the development of yellow rust **(Bahri, 2008)**. As a result, necrosis remains, most often, only from June onwards **(Syngenta, 2017).**

Cardinal germination temperatures are relatively low **(Bahri, 2008)**:

• Minimum germination temperature: 2°C

• Optimum germination temperature: 10°C

• Maximum germination temperature: 28°C

The following table summarizes the environmental conditions for the development of yellow rust as described by **Roelfs et al. (1992).**

Table 02: Environmental conditions for the development of yellow rust (Roelfs et al., 1992)

Yellow rust development stages	Temperature (^{0}C)			Light	Free water
	Minimum	Optimum	Maximum		
Germination	0	9 to 13	23	Low	Essential
Germling	NA	10 to 15	NA	Low	Essential
Penetration	2	9 to 13	23	Low	Essential
Growth and invasion	3	12 to 15	20	High	None
Sporulation	5	12 to 15	20	High	None

NA: not available, Source: (Roelfs *et al*., 1992)

There are other climatic factors that will also influence the development of the disease such as, for example, the wind whose timing and direction will play a major role in dispersal of spores and early infection **(Cereals White Paper: Yellow Rust, 2017)**.

Finally, a number of climatic factors can limit the degree of early field infection, so high temperatures in late summer will limit the amount of primary inoculum in the fall.

The frost will also have an impact on the spread of the disease. Indeed, the gel kills the mycelium when it is in sporulation, the spread of the disease during the harsh winters is limited.

a- Impact: Brown rust

Brown rust causes significant yield losses. These are generally smaller than those associated with yellow rust. However, this disease is the most common and widespread worldwide. It is found in all areas where wheat is present **(Cereals White Paper: Brown Rust, 2017; Huerta-Espino et al., 2011; Bolton et al., 2008).**

Yield losses caused by brown rust are often related to a decrease in the number of grains per stem and a decrease in grain weight.

b- Influence of climatic factors

Brown rust is associated with a warm growing season and average rainfall, according to the study by **Savary et al. (2016).**

The range of temperatures allowing spore germination and brown rust infection is very wide. Spores can germinate in temperatures ranging from 0°C to 32°C **(Savary et al., 2016).**

Infection can occur between 5°C and 25°C **(Savary et al., 2016)**. But, according to **Duvivier et al. (2016)**, the temperature range for infection is between 10°C and 25°C.

The latency period is correlated with temperature. It lasts eight to twenty days when temperatures are between 10°C and 20°C. The temperature optimum is 26°C. An 8 to 20 day period is required if temperatures are between 10°C and 20°C. **The Cereals White Paper (2017)** refers to a latency period between 8 and 12 days when the temperature is between 15 and 20°C (**Cereals White Paper: Brown Rust, 2017; Duvivier et al., 2016; Savary et al., 2016; Azzimonti, 2013; Bolton et al., 2008).**

The following table presents the environmental conditions for the development of brown rust as described by **Roelfs et al. (1992),**

Table 03: Segregation for leaf rust severity in F 2, F 3 and F 5 generations of two wheat crosses against leaf rust race 77-5 and stripe rust race 46S119

Rust/Cross	Generation	No. of plants with reaction				Expected χ^2ratio	
		Resistant	Segregating	Susceptible	Total		
Leaf rust							
HD2009 × WL711	F_2	471	–	23	494	15:1	2.14^{ns}
	F_3	85	70	9	164	7:8:1	4.35^{ns}
	F_5	101	–	23	124	3:1	2.75^{ns}
RL6058 × HD2009	F_2	342	–	0	342	255:1	–
Stripe rust							
HD2009 × WL711	F_2	441	–	40	481	15:1	3.50^{ns}
	F_3	77	112	17	206	7:8:1	4.02^{ns}
	F_5	125	–	33	158	3:1	1.43^{ns}

ns = non-significant at 5% level of significance

There are climatic factors that can influence the resistance of wheat to brown rust. For example, high temperatures can inhibit the development of brown rust pustules. Moderate temperatures can alter the resistance of the host plant's resistance genes, causing some varieties to become more resistant to rust, while others may become more susceptible **(McCallum et al., 2016).**

I.3.1. Impacts of climate parameters on durum wheat

Climate plays a key role in wheat development. But also sometimes is opposed to their growth and development, because climatic factors can act directly on the physiology of the plant.

I.3.1.1. Precipitation

The damage caused to the plant by the excess or deficit of the rains is not to be neglected, because the lack of rain leads to a decrease in yield. The only environmental factor commonly capable of preventing a well-managed crop from achieving adequate yield is drought, especially on shallow soil (Lafarge 1986).

Rainfall deficit can lead to yield losses on rainfed crops at any stage of wheat development.

CHAPTER 02

Geomatics and Geographic Information System (S.I.G)

Introduction

Based on methods dealing with studies placed in the regional or local context, which would involve the consideration of the interaction of environmental factors on a chosen scale, these methods are statistical, analytical and descriptive methods, they make it possible to materialize agro-climatic regionalization in different forms.

II -1-Mapping

With this tool, different parameters can now be represented in space, whether physical or natural **(Beguin and Pumain 2003).**

Two forms exist:

- Digital mapping, the introduction of which makes it possible to store information in the form of digitized files so that it can then be processed and reproduced automatically in the form of cartographic documents.

II -1-1- The digital mapping system

With the help of the cartographic digitization system, the conversion of existing elements into digital form is possible, in addition, the data base is developed, this is the most essential element, after having visualized the map.

The most common method of digitalization is to fix the map on a table to digitalize and trace the objects to be mapped using a cursor or a stylus. It is also possible to use the scanners to digitize the data (aerial photographs). The result of the scanner is a graphic image in place of the delimitation of objects, as the digitization table does. The scanner software produces graphic files in standard formats for the user to use. These files are subsequently imported into the S.I.G.

II-2-Geographic Information Systems (S.I.G)

The GIS is a technical support allowing a good visualization of the spatial data and therefore it presents a good perception of the evolution of the environment. It also all owns managers to have a global and synthetic approach to problems, among the existing definitions, we remind the most appropriate to our objectives.

II-2-1 Definitions

A Geographic Information System is a set of numeric data, geographically located and structured with in a computer processing system comprising functional modules for constructing, modifying, interrogating, represent the cartography, the database, according to semantic and spatial criteria **(Gilliot 2000).**

A Geographical Information System is a computer tool for representing and analysing all elements referenced geographically on the earth's surface (weather stations, land heights, agricultural land, etc.)**Beguin and Pumain, (2003).**

S.I.G. offers all the possibilities of databases (such as queries and statistical analyses), and alsoprovides a unique visualization and geographical analysis specific to maps. These specific apabilities make the S.I.G. a rare and unique tool, accessible to climate information cartographers and suitable for a wide variety of applications. The major challenges we face.

II-2-2-Geographic analysis systems

Geographic analysis systems are systems that have the ability to do traditional data base queries, to include the ability to analyze data based on their locations.

The traditional query of the data base is valid, if we have to deal with the attributes of the same object. But when the objects are different, the query is invalid. Indeed, there is a need for a system that has the ability to compare objects by their common geographic occurrences **(Denegre and Salge 2004).**

II-2-2-1-Spatial and descriptive database and database

According to **De Blomac et al, (1994)** the data base is the acquisition of information in the form of existing maps, the recovery of existing digital data, the collection of field data.

II-2-2-2-The data base management system

This system is traditionally defined as, a type of software that is used for the capture, management and analysis of numerical data. Thus, it can be used for these same tasks in S.I.G. However, we must recognize that spatial data are among the elements of the database to be manipulated. With the help of the database management system, descriptive data can been tired. These descriptive data consist of tabular and statistical results. Also this management system allows the user to extract spatial data and statistical summaries to make a report. The database management system makes it possible to carry out a very important task. The latter is the analysis of descriptive data on space objects **(De Blomac et al, 1994).**

II-2-2-3-Representation of information on S.I.G

According to **Denegre and Salge, (2004)** there are different modes of representation of geographic information in an I.G.P. of which the two main ones are:

II-2-2-3-1- The "Vector" mode

The boundaries of spatial objects are described through their elementary components or as a us ualentity: points, arcs, lines or polygons, these objects thus represented are identifiable. Each spatial object carries are cognizer to link it to a winning table.

II-2-2-3-2- The "Raster" mode

The initial information is broken down into a regular grid, represented in rows and columns. Eachmesh of this grid has its own significant colour. Thus, the juxtaposition of the dots recreates the visual appearance of the plane. It is therefore an image, a photograph or a plane represented by a grid of elementary pictorial cells commonly called «pixels».

The pixel

The digital data are encoded by pixels, the latter are only two-dimensional matrices possessing a number that shows the intensity of the electromagnetic radiation reflected in a given band.

III-2-3-The decision support system

Decision support techniques (advice) are the most important functions of the S.I.G. tool, but the programs for this kind of operation are rare in most systems.

III-2-4- Advantages of S.I.G.

According to **Gilliot, (2000),** in the field of automatic mapping, geographic information systems are required to perform several computer functions, thanks to its professional software. However, access to this technique is limited by many factors.

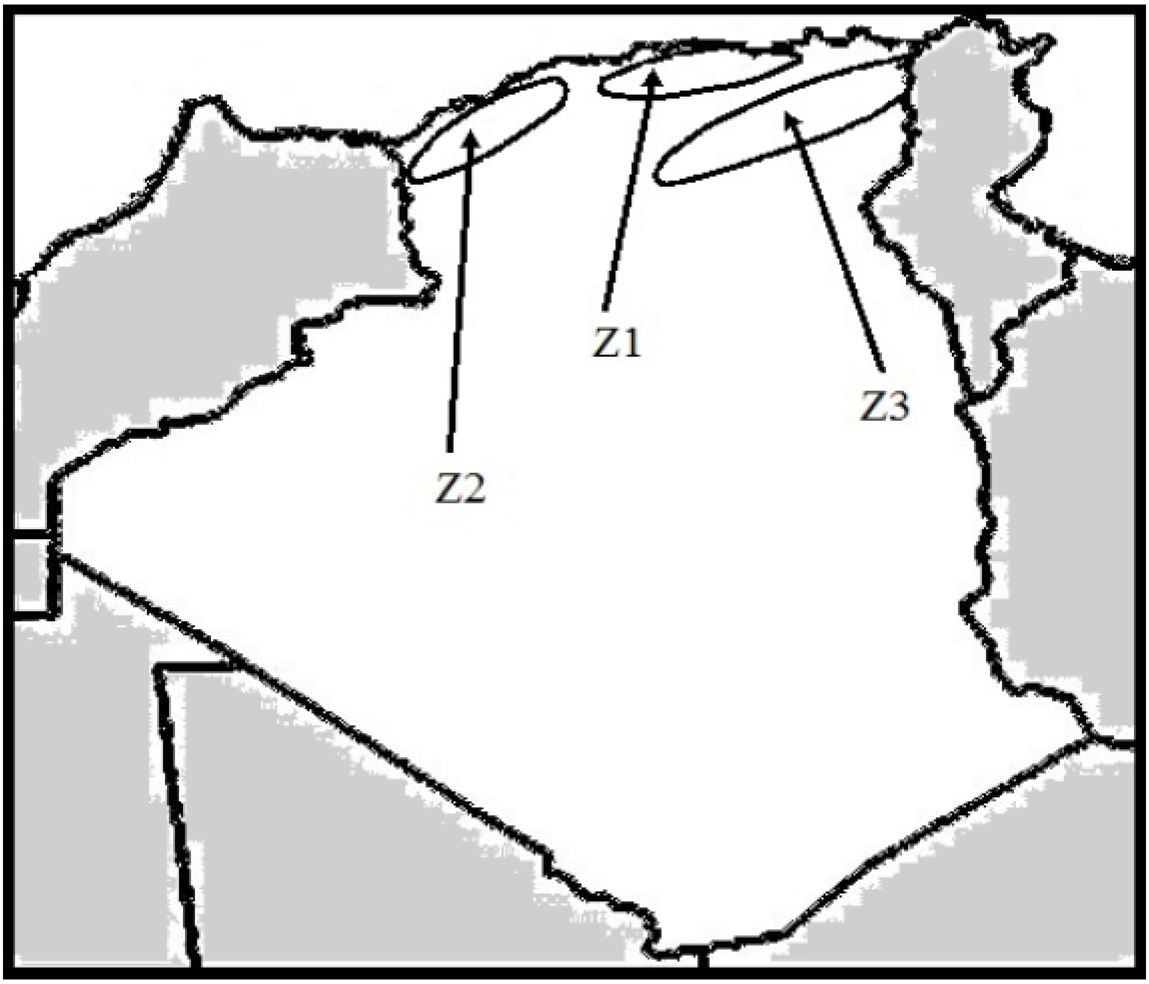
III-2-5-Terrain Numerical Model (M.N.T.)

A Digital Terrain Model is a digital file that regularly displays the altitudes of a geographical area. It is a data set consisting of a mesh of points, regular or not, that generates a referenced geometrical timeter information. It can be made using topographical, photogrammetric or image correlation methods **(Deleuze, 2005)**.

II -3-The geographical location of production

In Algeria, the production of cereals is a mission provided by the majority of the country's agricultural holdings, in fact, nearly 60% of the total workforce of Algerian agricultural enterprises contribute annually to the accumulation of the country's total production **(RGA, 2001)** by using almost 80% of the useful agricultural area, the growing air of these holdings extends from the coast to the high plateaus and certain Saharan areas5, but in order to better specify the boundaries of the geographical areas where cereals are predominant, this agricultural area can be divided in to three main cereal zones, the partition criteria being the amount of rain received during the year and the quantities of cereals produced:6

Figure 13: Location of cereal growing areas in Algeria.



- A high potential area (Z1): this area is characterised by an average annual rainfall of more than 500 mm, and its average annual yields are around 20 quintals per hectare, covering the following regions: the plains of Algérois and Mitidja, Issers basin, Soummam and Oued El Kébirvalleys, Seybouse valley… etc. the useful agricultural area over which this area extends is estimate data 400,000 ha, of which less than 20% is devoted to cereals.

- A zone with medium potential (Z2): this zone is characterized by an annual rainfall of between 400 and 500 mm, but may be subject to high climatic crises, its average annual yields may vary between 5 and 15 qx/ha, and it covers the following regions: the slopes of Tlemcen, the valleys of the Chélif, the Médéa massif… etc. This area has a UAA of 1,600,000 ha of which less than half is reserved for cereals.

- A zone with low potential (Z3): this zone is characterized by a semi-arid climate and is located in the highlands to the east, west and south of the Aurès massif, the average rainfall is less than 350 mm per year and grain yields are usually less than 8 qx/ha, this area covers an UAA of 4.5 million ha of which almost half is own each year in cereals.

II-4-New Durum Production Area Map

Through the map of the new durum wheat production area, we determined the new limits of areas with wheat production potential in the study area. These areas are determined according to the climatic, soil and morphological requirements of the durum wheat crop.

From a practical point of view, the creation of this mapis based on the superposition of layers of cartographic information. Each layer includes a synoptic data specific to a variable (precipitation, slope, soil classes, land use). The final map provides an overview of the areas that combine the best environmental conditions for rain-fed durum wheat production.

II-5-Digital precipitation mapping

Precipitation data from the study area allowed us to map the spatial and temporal distribution of precipitation over the period (1986 – 2006).

The annual and monthly digital precipitation mapping is based on the geostatistical approach. After determining the parameters of the multiple regression equation, it was necessary to estimate rainfall points in the study area. This operation required the design of arid with a square mesh pitch (15 km x 15 km) which allowed us to obtain 155 points. In addition, the operation also required the design of a MNT with a pixel mesh of (700 m x 700 m) and maps of residues by kriging. These maps allowed us to have the altitudes and the error of the mesh points.

II-5-1-Rainfall

Algerian agriculture is far from being considered as a developed agriculture with a high level of motorization and extensive irrigation systems, which makes it a high lyrain-dependent agriculture, Indeed, the random effect of rainfall remains one of the main determinants of the harvest volume not only of wheat but of all cereals, soit is likely that the effect of this variable will be positive and significant on production in the model.

II-6- Satilitary image

A satellite image is a graphical representation, from above, of a fairly large area of the Earth. The peculiarity of this image is that it is taken by a satellite placed in orbit around the planet.

Unlike images obtained with a camera, or drawn on paper, a satellite image is a digital image, processed by a computer tool, made from signals transmitted by a satellite.

II-6-1- LANDSAT 8

Launched in 2013, LANDSAT 8 provides high-quality multi-spectral images at 30 metres (15 panchromatic) resolution in visible and near-infrared mode (Operational Land Imager (OLI) sensor) and 100 metres in thermal infrared (TIRS (Thermal Infrared Sensor) radiometer with a 16-day repetition (time of passage to the equator at 10h GMT).

Each OLI scene represents an area of 185 x 185 km². Each band is supplied in luminance as a geoTIFF file georeferenced in UTM and not corrected for atmospheric effects (Level- 1T).

II-6-2- SENTINEL 2

The SENTINEL 2 mission involves a combination of two satellites (SENTINEL 2A and SENTINEL 2B) equipped with identical multispectral instruments (MSI) capable of acquiring data in 13 bands at different spatial resolutions (between 10 m and 60 m from visible to thermal infrared). The orbits are designed to provide about five days of repetitive passage to the equator (10h30 hours).

SENTINEL 2A was launched in June 2015, and is now operational, while SENTINEL 2B, launched on March 7, 2017, is still in the recipe phase.

Each MSI scene represents an area of 290 x 290 km². Each band is supplied as reflectance and corrected for atmospheric effects at the top of the atmosphere (TOA: Top of Atmosphere) in the form of a Jpeg2000 file georeferenced in UTM (Level-1C).

Table 04: Sentinel-2 Characteristics

Satellite	Sentinel-2A and Sentinel-2B
Altitude	786 km

Instruments	MSI, multispectral imager
Temporal resolution	5 days (Sentinel-2A and Sentinel-2B)
Spatial resolution	10-60 m
Number of spectral bands	13 (visible via infrared)

CHAPTER 03

Synthesis of geomatics methods for forecasting cereal diseases

1. Climate projection models (CPMs)

have predicted that agricultural productivity will be significantly affected due to the depletion of water resources with enhanced climate variability, the frequent occurrence of drought events, rise in average global temperature because of GHG emissions, and a five times increase in water demand deficits during the 21st century, which is a serious threat to global food security **(Hussain, 2010; Neupane, *et al*., 2021)**. Further, CPMs suggested that warmer temperatures and a reduced or seasonal redistribution of precipitation will lower maize yields if no sustainable adaptation majors are implemented by the mid and late 21st centuries **(Butler. Huybers, 2013; Jin. et al, 2017)**. The magnitude of the losses is predicted to be more severe in the regions with higher evapotranspiration rates (water vapor deficits**) (Basso et Ritchie, 2018)**. However, an indirect effect of higher temperatures on climate change includes shortening the number of calendar days allocated to the grain fill period by 15–25% because of less time for the starch deposition. Planting longer-season maize hybrids, which have the advantage of the additional thermal time for grain fill, can sustain or even increase maize yields under projected future climates compared to the currently used hybrids **(Abendroth; et al, 2021).** The Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2007) signals that a minimal increase in temperature can reduce agricultural productivity at lower latitudes and, at above two degrees of warming, can reduce potential yields in most regions of the globe. Further, **FAO (FAO, 2015)** concludes that over 800 million people are experiencing some form of food shortage in the food supply in recent years. A long-term study (1979–2016) conducted in China using a feasible generalized least square (FGLS) model to observe the impact of climate change on maize yield, reported the adverse effect of temperature on the maize yield, with a reduction in the maize yield by 5.2 kg from a 667 m2 study area (77.8 kg ha−1) for every 1 ◦C rise in temperature. However, the study reported a positive but overall negligible impact of precipitation on the maize yield **(Wu, 2021).** Another study reveals that climate change decreased global agricultural productivity by ~1–5% per decade over the last three decades **(Mashizha, 2019),** and it is predicted that a decline in crop production by over 82% would be observed over the next century due to climate change **(Bannayan.; et al, 2016).** Studies demonstrate a negative but significant relationship between agricultural productivity and climate change in African **(Soglo; Nonvide, 2019)** and Asian countries and regions **(Akram, 2013)**, which exacerbate food security and malnutrition problems in the regions. Combating global climate change and providing sufficient food (nutritional) and energy requirements for an ever-increasing human population are the greatest challenges in recent years **(Bevan; Waugh, 2007; Zenda, et al, 2021).** Expanding the global food supply, increasing agricultural productivity, and tackling nutritional challenges, while adapting to climate change, would seek alternative adaptative approaches over traditional approaches **(Mabhaudhi; et al, 2019)**. Thus, this necessitates developing climate-resilient crops that can maintain their productivity under extreme climate change scenarios, such as developing climate-resistant cultivars using conventional breeding techniques, as well as the use of modern molecular and genomic techniques **(Scheben.; et al, 2016 ; Pourkheirandish.; et al, 2020)**.Another approach to combat climate change while maintaining crop productivity would be the application of agronomic best management (ABM) practices, including an improvement of irrigation and fertilizer use efficiencies. Further, replacing resource-intensive crops with the less intensive crops, for example, millet (Panicummiliaceum L.), which use minimal amounts of water and fertilizer inputs compared to rice and maize, and are adapted to marginal lands, would be our major target for achieving food and nutritional security **(Wang.; 2018).**

Therefore, this article provides a comprehensive review on the area and production ofthe top three cereal crops, their growing conditions, greenhouse gas (GHG) emissions from different crops, the response of climate change on cereal yields, and the morphological, physiological, biochemical, and hormonal response of plants to drought. This review also highlights the strategies to combat climate change and increase crop yield.

2. Monitoring the Environment through Remote Sensing

As suggested by **Thomas et al (1994),** monitoring is one of the essential methods for dryland research. In fact, monitoring should observe the dynamics of the environment, discern and measure its changes, integrating the spatial and temporal dimensions of its degradation. However, **Lambin (1997)** pointed out that measuring soil degradation is particularly difficult because there is a strong interaction between normal or random variability in rainfall and anthropogenic changes in vegetation cover. Therefore, monitoring is a thorough investigation in which any factors leading to misunderstanding must be taken into consideration.

The field survey carried out at different dates is the most direct monitoring method, by which we can directly observe and dynamically trace the environmental situation in the area concerned. The imperfection of this method lies in its limitation to obtain regional and global data on land use patterns and their changes over a given period of time, with limited financial support. Remote sensing techniques overcome this limitation by using various sensors that can be installed on different platforms, such as artificial satellites or aeroplanes, and can regularly scan the earth's surface or the area of interest and acquire multi-temporal dynamic information about the environment. However, the interpretation of remotely sensed data may occasionally encounter difficulty when these data are used to analyse subtle change. Therefore, the combination of field survey (with GPS) and remote sensing seems to be a more suitable method to to carry out monitoring.

As early as 1963, Verstappen began to use aerial photographs and field surveys to measure coastal change. This is probably the first detection of environmental change by remote sensing. Since then, change monitoring has become one of the main applications of spatial data. Several authors have undertaken this kind of study and many reference documents could be listed on this subject. Choosing to limit ourselves to a certain period, here is a list of examples mentioned in this research.

Anuta (1973), Rifman et al. (1975), Swain et al. (1976), Weismiller et al. (1977), Todd (1977), Nelson (1983), Tucker et al. (1984, 1986), Justice (1986), Malingreau et al. (1989), Skole et al. (1993), Lambin et Ehrlich (1994, 1997a, 1997b), Mertens et al. (2000), Wu et al. (2002a and b), etc., used satellite data to distinguish and monitor various types of environmental change such as urban development or urban fringe. Forest change, deforestation, coastal change, land use changes in agriculture, etc. Their research is the basis for creating an effective algorithm for monitoring change. Some research on remote sensing applied to arid areas by **Courel (1985), Hellden (1984, 1988, 1991), Tucker et al. (1986, 1991), Graetz et al. (1988), Price et al. (1992), Zhu et al. (1993, 1995), Lambin et al. (1997a and b), Wu et al. (2002a)** are particularly worth mentioning. Their research covered both the monitoring of the main phenomena such as the mutation of surface albedo, the desertification of pasture, the change of land use, the degradation of the ecosystem and the modelling of the human-The results of remote sensing treatment were used. These successful examples provide good leads for this thesis to define algorithms for environmental monitoring. A brief introduction will first address the principle.The European Commission's Directorate-General for the Environment, Research and Development, Research and Technological Development, Research and Technological Development.

2-1- Basic principles of remote sensing

Origin

Remote sensing was first used in **1955 by Dr. Evelyn** Pruitt of the United States Naval Research Office to bring together aerial photography, and satellite imagery. And other forms of remote data collection. Usually it is defined as the science, technology or art of obtaining information about objects or phenomena remotely **(Microsoft Encarta Encyclopedia, 2001).** Strictly speaking, any means of obtaining information remotely is remote sensing. From a practical perspective, this term refers to the collection, processing and retrieval of environmental information on Earth.

Remote sensing technology can date back to the 19th century. The invention of photography in **1839 by a French inventor, J. Daguerre (1787-1851)** gave birth to photogrammetry**. In 1858, another Frenchman, Felix Tournachon (under the pseudonym of Félix Nadar) (1820-1910),** took the first photograph from a balloon and filed a patent for the new system of aerostatic photography giving an overview of the topography, hydrography and cadastral data seen from the sky **(Chen, 1984; Encyclopedia Microsoft Encarta Standard, 2001).** The success of the Wright brothers' flight in 1903 led to the application of airborne photography. In 1957, the successful launch of satellites in the former Soviet Union and then in the United States in 1958, with in particular the **Landsat satellite of NASA (United**

States) in 1972, opened a new era of peaceful use and civil application of remote sensing techniques. Since then, various sensors optical, radar but also a variety of platforms, such as balloon, aircraft and satellite have been developed for various applications. Remote sensing was then widely applied in many fields: geographical and geological mapping, inventory of natural resources, environmental monitoring, land use study, estimation of agricultural productivity, weather forecasting, atmospheric and ocean studies, military detection, etc.

Principle

The principle of remote sensing, as presented in its definition above, is based on the acquisition of radiation or reflection signals of the object, for example, land use, by a remote sensor installed on different platforms (such as aircraft, satellite) using visible bands, infrared and microwave. The perception and recording of the natural radiation or reflection of the solar energy of objects is called passive remote sensing. The visible and infrared multiband trace of ground surface information is an example. On the other hand, when it comes to illuminating specific objects and then collecting the information from the reflection of the energy emitted by the platform itself, the process is called active remote sensing. Radar is an example.

Dispersion, Absorption, Effect and Atmosphere Window

Solar energy arrives on the ground in the form of a series of electromagnetic waves, such as X-rays, ultraviolet rays, visible rays, infrared rays and radio waves. However, due to the absorption and atmospheric dispersion experienced by certain wavelengths of solar energy, all radiation energy cannot reach the Earth’s surface and therefore the radiation and signal intensity from the target to the sensor are attenuated. This phenomenoniscalled the atmosphericeffect.

With regard to dispersion, two different forms are discernible in the atmosphere: Rayleigh and Mie. Rayleigh usually appears when the radiation interacts with atmospheric molecules or other particles with a diameter significantly smaller than the wavelength of the radiation. The dispersion effect of Rayleigh is inversely proportional to the fourth power of the wavelength **(Curcio 1961; Lillesand et al.,**

1979 and 1994; Richards, 1986 and Chavez, 1988). Therefore, there is a high probability that the waves are more threatened by this dispersal mechanism than large waves. The "blue" sky is a manifestation of Rayleigh dispersal, as the earth's atmosphere disperses short-wave (blue) rays more significantly than other wavelengths in the visible band when the sun's rays interact with the atmosphere. The reddish glows of sunrise or sunset are also caused by the dispersal of Rayleigh since, the distance at these times promotes the dispersion of most of the short wave radiation relative to a longer wavelength. The dispersion of Mie or aerosol exists when the sun's rays interact with larger atmospheric particles such as water vapour, smoke, and mist. These particles are in the order of one tenth to one of wavelength. Thus this dispersion is also dependent on the wavelength, although not as clearly as the dispersion of Rayleigh. When particles are much larger than the wavelength, such as fog, cloud and dust, dispersion is no longer dependent on the wavelength and becomes non-selective **(Lillesand et al., 1979, 1994; Richards, 1986)**. In a clear ideal atmosphere, Rayleigh dispersal is the only mechanism present **(Richards 1986).**

The radiation energy is selectively absorbed by the atmosphere through which it transmits radiation to the Earth or the sensor. Such a phenomenon is called atmospheric absorption. The main components of the atmosphere that absorb solar energy are water vapour (H2O), carbon dioxide (CO2), oxygen (O2) and ozone (O3) **(Lillesand et al., 1979, 1994, 2000; Chou et al., 1995)**. Ozone mainly absorbs ultraviolet rays; carbon dioxide, medium infrared and thermal rays. Water vapour also plays a significant role in reducing the intensity of near-to-medium infrared rays. Therefore, atmospheric absorption attenuates the solar radiation emitted to the Earth.

The ranges of wavelengths for which the atmosphere is particularly transmissive or transmittance (we will adopt this term to define the ability to transmit) of high energy are named: atmospheric windows **(Lillesand et al., 1979, 1994, 2000; Chen, 1984; Chou et al., 1995)**. Figure II-1 shows the locations of these windows in the electromagnetic spectrum. In order to collect remote sensing data, it is essential to select transmissible ranges.

The windows known and already used for this purpose are **(Chen 1984)**:

1. Photographic windows (0.3-1.3 m): including all visible, some ultraviolet (0.3-0.38 m) and near infrared (0.76-1.3 m). This range of energy can be widely transmitted through the atmosphere (> 90%). In addition, this window can be used to obtain and record electromagnetic information of objects through photography. This is why this electromagnetic wave section is the most frequently used in remote sensing.

2. Medium infrared (1.5-5.5 m): with a transmittance of 50-90% depending on the wavelength. There are two significant transmission valleys at approximately 2 m and 2.5 m due to water vapour (H2O) and CO2 absorption. This window can thus be divided into three sub-windows at the respective wavelengths of 1.5-1.8 m, 2.1-2.4 m and 3-5.5 m. The radiation and reflection information of objects on the surface of the globe can be detected by the scanner but not by the camera.

3. Thermal infrared (8-14 m): at a transmittance of about 60-70%, it is used for the detection of thermal radiation from objects on the surface; and

4. Microwave (8mm-1m): Total transmission window (100%) used for radar detection.

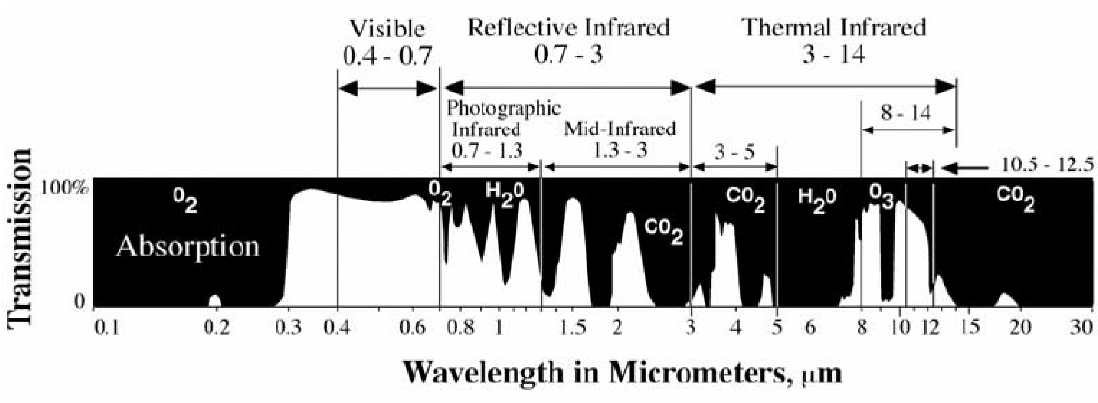


Figure 14: **Atmospheric windows in the electromagnetic spectrum**

SPECTRAL REFLECTANCE

The reflectivity characteristics of objects on the earth's surface can be quantified by measuring the reflected part of the incident energy. What is measured as a function of wavelength is called spectral reflectance and can be expressed as a percentage **(Lillesand et al., 1979, 1994; Chen, 1984).** A graph of the reflectance of an object as a function of wavelength is called a spectral reflectance curve. The configuration of such curves gives us indications of the spectral characteristics of an object and strongly influences the choice of wavelength regions in which remote sensing data are acquired for a particular application **(Lillesand et al., 1979, 1994).** Figure 14 shows the spectral reflectance of three common compositions of Earth’s surfaces in the range of visible, infrared and near-midinfrared.

For healthy vegetation, chlorophyll absorbs energy at a wavelength of about 0.45 m (blue) and 0.67 m (red) and has a reflection of about 0.55 m (green) in the visible spectral range. This is why we perceive healthy vegetation as green. With the increase in wavelength from 0.76 m to 1.3 m in the near infrared section, the vegetation strongly reflects energy and shows high reflectance. However it decreases in the medium infrared range and significant dips occur at about 1.4 m, 1.9 m and 2.5 m, because the water in the leaves absorbs strongly, at these wavelengths. If the plant is susceptible to disease or is threatened by an insect, the chlorophyll concentration of the leaf will decrease and lead to less absorption in the blue and red bands. The leaf then turns yellow due to the increase in red and blue reflectance.

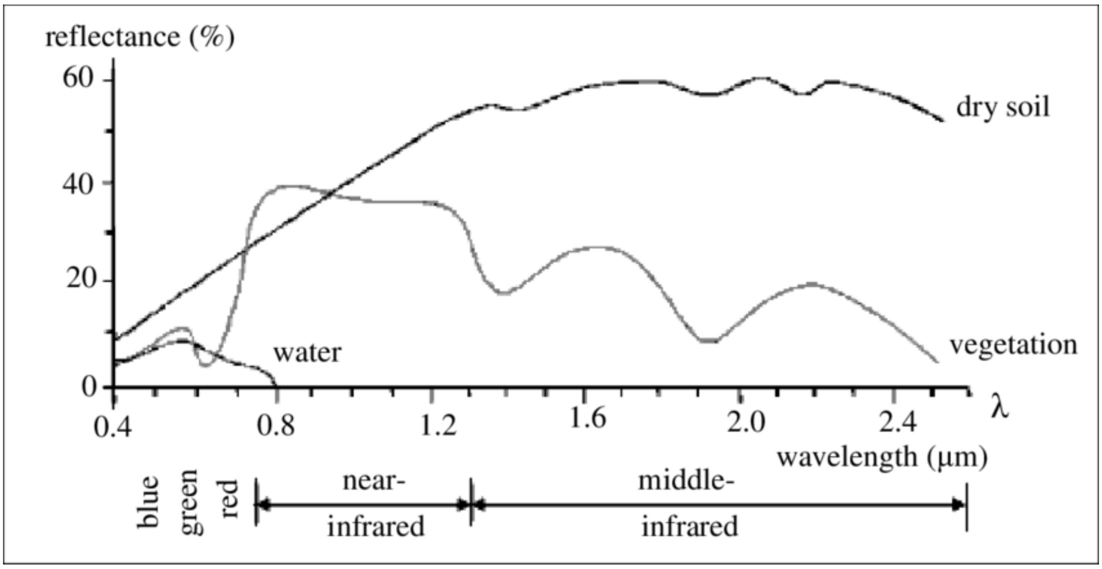


Figure 15: Characteristics of the spectral reflectance of the common materials of the soil surface, in the visible and near-medium infrared (d'après Richards et Jia, 1999).

The bare dry soil shows an increase in reflectance with regard to the wavelength but also decreases to about 1.4 m, 1.9 m and 2.5 m, due to the humidity. Soil reflectance depends on moisture, organic content, composition texture and surface roughness.

The clear water seems to have only a weak power of reflection in the visible. However, with the change in water turbidity, the transmittance and reflectance of the water change markedly **(Lillesand and a1., 1994).**

The positions of the spectral bands for common remote sensing instruments are shown in Figure

Spectral Bands in Remote Sensing

Based on the spectral reflectance characteristics of different objects, a series of wavelength ranges of the spectrum was used to scan and detect Earth's surface information. These wavelength ranges are called spectral bands. Each band has a specific sensitivity for certain object(s) so that it can be applied to scanning or recording the characteristics of such an object. If we look at Landsat MSS, TM, ETM+ and SPOT HRV and HRG.

DIGITAL DATA

It was not until Landsat-1 was launched in 1972 that digital image data became widely available for the application of remote sensing to the study of the Earth (**Lillesand et al., 1979).** The word "image" acquires a rather general meaning in this context. An image is no longer simply a reproduction or a simple photographic, it is also a two-dimensional array of numbers, small spatially distinct elements radiometrically representing their level of brilliance **(Schowengerdt, 1983; Richards, 1986).** These small elements are arranged in a rectangular grid and referred to as pixel in raster format. The brightness value or gray level of each pixel is also called the numerical count (NC) or the numerical number (DN). The size of the pixel, referred to as the Instant Visual Field (IFOV), depends on the resolution of the sensor. The IFOV of Landsat TM or ETM + is 30m 30m, that of SPOT HRV 20m 20m, and that of SPOT HRG 10m 10m. The smaller the pixel size, the more detailed the contents of the digital image will be.

To facilitate computer processing, data from digital images are usually saved and stored in a binary format. The numbers in the binary system are referred to as bits **(Showengerdt, 1983)** Thus at 8-bits, the brightness values, or pixel digital counts, have 256 (28) possible levels in a decimal system with a possible variation from 0 to 255 (28-1); for 16-bits, from 0 to 65535 (216-1). The group of bits representing each pixel is called byte. The most common binary system used in remote sensing is 8-bits. Much of the Landsat MSS, TM and SPOT images are stored in this format, in which the pixel gray level ranges from 0 to 255. More recently, Landsat ETM+ images were frequently recorded in 16-bits, with their grayscale ranging from 0 to 65535.

The advantage of digital data is that the image can be processed digitally by computer to extract relevant information, using a series of procedures, for example, pretreatment (radiometric and geometric rectification), reinforcement, transformation, classification etc. These procedures will be presented in the following sections.

3-Analysis of human-environment interaction

Introduction

Throughout their history, human activities such as agricultural crops, urbanization and deforestation have been constrained, to a certain extent, by natural conditions and have simultaneously caused environmental change and even degradation. To assess the development potential of natural resources such as soil or to predict the trend of environmental change, one must know the trajectory of past change, understand the training forces of such a change and estimate the likely future evolution. Consequently, the analysis of the interaction between man and nature has been increasingly considered, in recent decades, as essential in the search for the environment. However, environmental change is a complex process caused by human and natural factors. It is hardly possible to perform a perfect simulation to model the process of change. Modelling is therefore an attempt to approximate the mechanism of environmental change and to estimate its future evolution.

Environmental change modelling dates back to the early 1970s. The approaches frequently used are the Markov chain, the logistic function model, the regression model, the spatial statistical model, the dynamic spatial simulation model, etc. According to **Lambin's analysis (1994)**, all of these models can be classified into three main types based on their ability to answer the three relevant questions: why, when and where will environmental change, such as deforestation, occur? The different models serve for the different questions and are essentially complementary. The regression model can indicate the training causes or forces and answer the question why. The Markov chain and the models of the logistic function indicate the probability and rate of temporal change and answer the question when. The spatial statistical model studies the probability of change in space by answering the question where. More complex models such as dynamic spatial simulation models seek answers to all of these questions.

The objectives of modelling are to improve our understanding of the forces governing environmental change, to describe quantitatively the relationship between man and environment, and to predict temporal evolution, especially for the future.

3.2. Approaches to Modelling

As mentioned above, several approaches for environmental modelling are really usable. The Markov chain, which stochastically describes processes going through steps, from a state tothe other was originally studied by **A. A. Markov in 1906 (Dynkin 1960).** It has been applied to geography , to land use change by **Burham (1973), Bell (1974), Bell et al. (1977), Robinson (1978),** and to deforestation by **Miller (1978) and Nualchawee et al. (1981). Wang et al. (1980 and 1992)** applied this theory to the birth and death process in demography. Its advantage lies in its mathematical and operational simplicity **(Lambin, 1994).** To study changes in land use, the central mechanism of the Markov chain is a probability, pij, which refers to the probability of transition or movement from the i state to the j state within a known time interval, represented by the fraction or percentage of land use of different types. The Markov process for the distinct landscape model can be expressed as follows **(Lambin, 1994)**:nt+1 = M nt ; where nt is a column vector, nt = (n1,….nm), whose elements are the sector fractions of the terrain in each of the m time states t and M is a mm matrix whose elements, pij, are the transition probabilities during the time interval t to t+1. In case of difficulties in understanding the dynamics of change and its other impacts, such a probabilistic model makes it possible to better understand the process of change.

The logistic function model, mathematically depicting the S-shaped curves, was first applied to biology by **Verhulst in 1845** to simulate the stabilization of population growth in a resource-constrained environment. **Palo et al. (1984, 1987), Esser (1989), Grainger (1986, 1990), Reis et al. (1990) (see review by Lambin, 1994)** then used it to model deforestation rates.

The dynamic spatial simulation model, is in fact a dynamic ecosystem simulation model, highlighting an analysis of the interaction of all the components forming the ecosystem, such as ecological condition, land use, deforestation, decision-making and human socio-economic activities, and using mathematical or statistical tools. Have developed some models for assessing ecosystem impacts of land use change, such as deforestation. Such models are the most advanced modeling approaches for a complex, dynamic and spatial problem. They can predict temporal changes in the environment, determine where the change will occur and can probably be effectively linked with remote sensing data for the calibration and validation of models **(Lambin, 1994).**

However, the question of why should be resolved before such a model is developed. Recently, **Barbier et al. (1990), Howarth et al. (1992), Willinger (1997)** proposed sustainable development modelling. An attempt to prove the interaction between economics and the environment, by determining the criteria of sustainable development and using different mathematical models.

However, the most common approaches used in modelling environmental change are regression models and spatial statistical models. These two models will be presented in particular in the following paragraphs.

3.3. Regression Modelling

Regression analysis can be roughly defined as an analysis of the relationships between variables. It is one of the most widely used statistical tools, due to the simplicity of its method, to establish a functional relationship between variables **(Chatterjee et al., 1977, 1991)** or evaluate the relationship between one or more independent variables and a single dependent continuous variable **(Kleinbaum et al., 1978, 1998)**. His mathematical formula is as follows **(Chatterjee et al., 1977 and 1991; Kleinbaum et al., 1978 and 1998; Cohen et al., 1983; Lambin, 1994):**

Environmental changes are spatio-temporally complex processes linked to natural factors (climate change, occurrence of natural disasters) and human activities (land use change, exploitation of natural resources). By considering environmental change as a dependent variable and human and natural factors as two groups of independent variables, regression models could distinguish which parameter(s) among the two groups is (are) the most important(s) for environmental change by reporting them using the equation.

Regression modelling can be calibrated in two different ways: either by cross-sectional analysis, that is, at a precise moment and across a large number of places; or by panel analysis, that is, by linking a change variable over a given time interval with changes in independent variables over the same time frame across a large number of locations **(Lambin 1994).**

Cross-sectional analysis transversally links the environmental element(s) with socio-economic factors at a given time.

The panel analysis describes the relationship between environmental change and changes in human socio-economic elements.

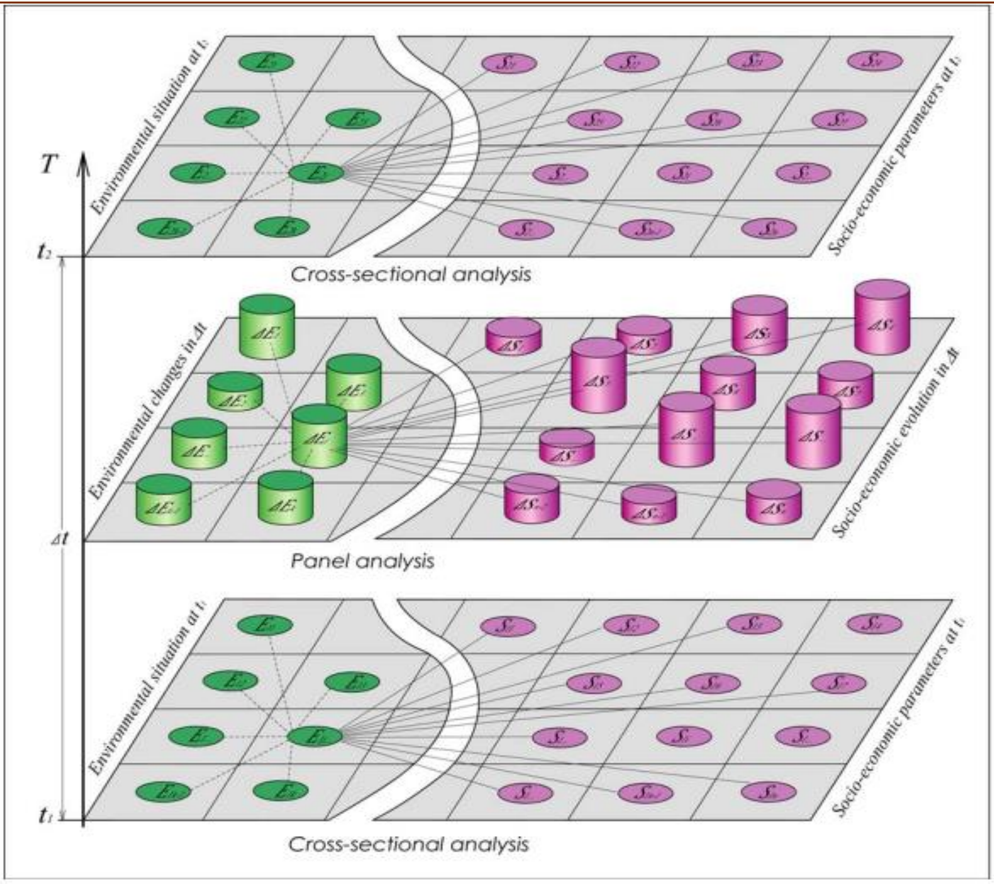


Figure 16: Analyses of human-environment interaction, by regression models

Regression models can answer the question of why by allowing us to identify the most important variables associated with environmental change, or perhaps even help predict when the change will occur. if the mechanism producing the changes remains unchanged **(Lambin, 1994).** Successful use of such models to understand spatial determinants and driving forces of deforestation and land use change by **Allen et al. (1985), Lambin (1994,**demonstrates their potential for research into the arid environment. However, regression modelling is not a spatial analysis and therefore cannot be used to answer the question where.

3.4. Spatial Statistical Modelling

Spatial analysis is a set of methods and techniques for analyzing events at a variety of spatial scales; its results depend on the spatial organization of events

(Goodchild et al. 1992; Fischer 1999). Events can be represented by points, lines, surface objects or space primitives, located in the geographic space and possessing a series of other attributes. Localization, topology, spatial organization, distance, and spatial interaction become the focus of spatial data analysis **(Fischer, 1999).**

Two other types of information are practically integrated into spatial analysis: location information (geometric/topological) concerning spatial objects and attribute information on relevant spatial objects such as socio-characteristicseconomic and physical (referred to as the primary attribute expression) and the relationship between spatial objects (secondary attribute).

Analysed the specificity of geographic information in two essential respects. The first is expressed in the famous Tobler Law First law of Geography: all things are related but those that are close are more connected than those that are remote **(Tobler, 1970 and 1979).** Such a property is called spatial dependence or autocorrelation. Thus, spatial dependence implies that data for particular spatial units are related and similar to data for other neighbouring spatial units. In other words, spatial autocorrelation occurs when there is a relationship between the observations of one or more variables at a specific point in space and another point in space **(Getis, 1999).** The second is spatial heterogeneity, presenting the propensity of geographic data to vary in such a way that conditions at a particular location will not be identical elsewhere. Statistically, this design corresponds to non-stationnarity. These special features of spatial data make conventional statistical methods unreliable unless they have been modified to fit the current spatial problem **(Fischer, 1999).** These spatial information properties require that the analysis be treated in particular.

The objectives of spatial analysis are the detection of spatial data modes, the exploration and modelling of the relationship between such modes, the enhanced understanding of the processes that could be responsible for these modes, and improving the ability to predict and control events occurring in the geographic space. It is precisely this focus of spatial analysis that distinguishes spatial data analysis from other forms of data analysis **(Goodchild et al. 1992; Fischer 1999).**The developments that spatial analysis has experienced in recent decades are listed as follows:

(1) Spatial regression modelling—an extension of the traditional linear regression model to spatial data analysis—is used to measure spatial autocorrelation, spatial association, and heterogeneity **(Cliff et al., 1973, 1981a and 1981b; Griffith, 1988; Fischer, 1999; Getis 1999).**

(2) Bayesian probability statistics used for the exploratory inductive analysis of spatial data **(Aspinall, 1992; Aspinall et al., 1996).**

(3) Logistic regression modelling has increasingly attracted the attention of geographers, biologists and environmentalists in recent decades, because of its ability to analyze explicit causes in space and to predict potential changes in the ecosystem. With the improvement of analytical capabilities of GIS and associated software (for example, SAS, SYSTAT, SPSS), this modeling technique has been frequently used to solve ecological problems.

4- Modelling and impact of climate parameters on wheat production

4.1. The approach in modelling

Summarizes the main steps of modelling. The development of a model depends closely on the objectives of the modeller (and the problem of the study) as well as his knowledge of the system studied and the experimental data available to him. Together, these constraints define the spatial and temporal scales of the model, the level of detail (i.e. the processes to be modelled) and the modelling method to be used **(Coquillard and Hill, 1997).** The usefulness of introducing additional complexity into models is not obvious **(Hakanson, 1995),** the true virtue of the modeller in its ability to represent the studied system sparingly. Very often, the chosen study scale (spatial and temporal) orients model designers towards an essentially descriptive approach (empirical models) or on the contrary mainly explanatory (mechanistic models) processes identified as important to model for the study scale considered **(Bolte et al., 2006).**

This also often affects the degree of complexity of these models. Knowledge of the system is also decisive for the choice of the representation of the functioning of the system. Thus, in situations where mechanisms are still poorly understood, essentially empirical models can provide more reliable predictions than complex models **(Bolte et al., 2006).**

Once the model is developed, it is appropriate to evaluate or “criticize” its outputs **(Thornley, 2001).** This step is essential to the modelling approach and is based on the comparison of simulated values to experimental data. The validation of a model aims to quantify situations (e.g. pedoclimatic) where the predictions of this model are "valid", that is to say close to the observations measured in real conditions. This allows to define the validity domain of the model as well as its robustness. Once the model has been evaluated or validated, the simulated values can be used to understand the functioning of the systems studied and to respond to the problem.

The haloed spot in the wheat leaf

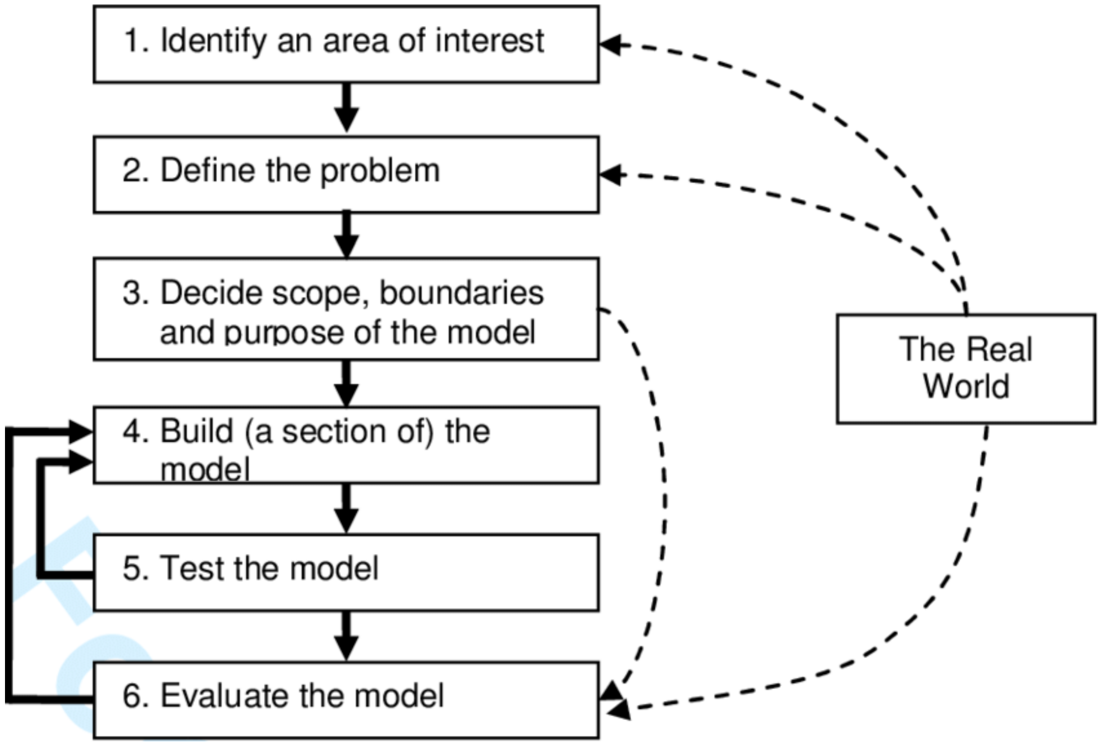


Fig. 17: Steps in the modelling approach

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4.2. Culture Models

4.2.1. Description, classification and use

Crop and plant sciences represent an integration of several domains (biology, physics and chemistry, climatology), and plant and crop simulation models are a mathematical representation of this complex system **(Hoogenboom, 2000).** Crop models are among the most widely used and effective tools in all areas of agricultural research. The development of new crop models and the improvement and adaptation of existing ones, however, continue to be one of the main concerns of agronomic studies.

Crop models, also known as ecophysiological models, are tools that use mathematical descriptions of physiological, chemical and physical processes, bringing together as much knowledge as possible about the plant (physiology, environment, crop management) to predict plant growth, development and yield over time and under specific environmental conditions **(White and Hoogenboom 2010).** Culture models are physiologically based on the principle of causal relationships between the different functions of the plant and its environment, but in reality they cannot take into account all the interactions between the environment and the modelled system and therefore may include assumptions, especially where information on certain aspects of the system is insufficient, incomplete or nonexistent **(Hoogenboom 2000).** Depending on the scientific discipline, there are different types of models, ranging from very simple models based on a single equation to extremely advanced models that include thousands of equations. Thus, crop models can be classified as follows:

A - Growth models

They include simplified mathematical representations of complex physical, chemical and physiological mechanisms in relation to plant growth. They are mainly used in research applications, but are not very practical for agricultural applications, given their complexity and the need for many input parameters **(Richie, 1998).**

B - agro-meteorologicalmodels

These are models that provide daily information on how the plant responds to a selection of weather-dependent variables **(Baier 1979)**. Agro-meteorological models are among the simple approaches to crop simulation, based on the use of agro-meteorological variables as a key input **(Hoogenboom, 2000)**. Their success depends heavily on their ability to quantify the influence of climate, soil and crop conditions in the simulation of crop development, growth and yield **(Hansen and Jones, 2000)**. They are used operationally in many parts of the world to monitor the effect of climatic conditions on crop growth and to forecast yields on a regional and continental scale **(Challinor et al., 2004; Hansen et al., 2004; Nemecek et al., 1996; Thornton et al., 1997; Vossen and Rijks, 1995; Yun, 2003).**

C - Statistical models

In these models, one or more variables representing climate, soil characteristics or time are statistically or empirically related to yield or other crop parameters **(Baier 1979; Ritchie 1998).**

D - Empiricalmodels

These models include equations or empirical relationships to represent the different complex processes of the plant and their interactions with the environment **(Baier, 1979; Ritchie, 1998).** Major uses of crop models include improving information about plant growth under given environmental conditions, and predicting the impact of future climate change on plant growth. Indeed, these models are the dominant tool in climate change impact studies on agrosystems in the third and fourth IPCC reports **(Gitay et al. 2001; Easterling et al., 2007).**

4.3. Expected impacts of climate change on durum wheat crop

Wheat is the most important food source for both consumption and production **(Tilman et al., 2002).** Together with rice and maize, it forms the basis of global food and animal nutrition **(Evans and Fischer, 1999).** Projections based on the growth of population growth (assumed to reach 3 billion humans) suggest an increase in wheat production and total productivity of 50% over the next 30-40 years: its flexibility in terms of food use and adaptability means that its importance should increase in the future and that it will take the place of some other cereals, especially rice in Asia. This is expected to occur under future climatic conditions with air concentrations of up to 1000 ppm CO2 resulting in an estimated 28% fertilizing effect (Oleson and Bindi 2002)but also by higher temperatures and more frequent and severe droughts.

In order to understand the possible impact of the different future climatic components on this crop of prime importance, numerous studies have been conducted in different regions across all continents **(Ghaffari et al., 2002; Scott and Maxwell, 2007; Xiao et al., 2008; Yunzhou et al., 2010; Moriondo et al., 2011; Sommera et al., 2013).** In the following, we will detail the response of the development and production of the durum wheat crop to the main projected climatic conditions, namely the increase in the CO2 concentration of the air, increasing temperature and variability in rainfall patterns and frequency of extreme events.

4.4. Impacts of climate parameters on durum wheat

Climate plays a key role in wheat development. But also sometimes is opposed to their growth and development, because climatic factors can act directly on the physiology of the plant.

4.4.1. Precipitation

Although rain is essential for the plant and for the production of a soil, nevertheless, the damage caused to the plant by the excess or deficit of the rains is not to be neglected.

The lack of rain leads to a decrease in yield. The only environmental factor commonly capable of preventing a well-managed crop from achieving adequate yield is drought, especially on shallow soil **(Lafarge 1986).**

Precipitation in its solid forms (snow and hail) can have bad influences on the plant. Snow protects from the cold, but a thick, long-lasting snow cover has negative consequences for the vegetation. Grain crops (wheat and barley) are rotting.

Plants have critical stages in relation to the water deficit at the time of their development. For maize, a lack of water can lead to a yield drop of up to 50% **(Lafarge, 1986).** Also for wheat, an excess of water during flowering can be manifested by the coulure (poor fertilization of the flowers).

Rainfall deficit can lead to yield losses on rainfed crops at any stage of wheat development. In durum wheat (Triticum durum Desf.), in the Mediterranean region, drought is one of the main causes of yield losses, which vary from 10 to 80% depending on the year **(Nachit et al., 1998 in Semcheddine, 2009).**

4.4.2. Temperature

Temperatures vary considerably around the Mediterranean basin, depending on the distance from the sea (the effect of continentality is very marked).

In the highland regions, the action of temperature on plant growth is specific. It has been observed that the spring wheat shoot explosion is not related to vegetation cover characteristics but to a rapid increase in temperatures **(Duru, 1986).** Another very important specificity is that of the consequence of low temperatures in spring which limit the growth rate. Indeed, it has been found that cereals generally have limits to this parameter, when the average temperature does not exceed 19 C°, wheat does not ear, while good germination of wheat requires a minimum temperature between 0 and 5 C°.

Winter frosts rarely affect wheat above 1000 metres, in years when the cold occurs without snow on the ground. Most cultivated wheats have limited resistance to cold, but damaged areas are usually replaced by later tallies, the major disadvantage will be a delay in the development of some cultivars **(Baldy 1993).**

In addition, high temperatures also affect wheat development:

- Early seeding may cause emergence to be too rapid, and there is an imbalance between the aerial (too fast growth of the beetle) and the underground (insufficient development of the seminal roots, which fail to supply the seedlings with water);

- During the run, high temperatures above 30 C° are generally unlikely. However, in some years, temperatures are high, and the rate of wheat development will be greatly accelerated;

- After flowering, high temperatures have adverse effects on grain development. Temperatures above 30 C have negative effects on the transfer and storage of assimilas and grain quality. It’s the phenomenon of scalding.

According to **Duru, (1986)** a global warming of about 3°C could lead to a contraction of natural areas of vegetation due to aridity and a slight rise in vegetation levels with a decrease in productivity.

It can be said that sufficient resistance to the winter cold, during pruning and the beginning of the run, then a relatively late flowering and a rapid maturation, are important assets to obtain a regular yield of the wheat in semi-mediterraneanclimatearid, particularly at altitude **(Baldy 1993).**

4.4.3. Evapotranspiration

The evapotranspiration representing the climate demand is closely related, even functional, to the elements of the climate, namely: temperature, humidity, wind, and radiation. Evapotranspiration is a complex phenomenon that results not only from physical processes such as changes in water state, molecular or turbulent diffusion of water vapour, but also from biological impacts such as stomatic regulation, leaf surface or root development **(Wardlaw 2002).**

4.4.4. Humidity of air and wind

Air humidity and wind are considered parameters regulating the FTE, as a decrease in the percentage of moisture in the air is associated with an increase in wind speed, which also leads to an increase in climate demand. In addition, humidity associated with favourable ambient temperatures create favourable conditions for the installation of diseases that are created, in particular, cryptogamic diseases specific to cereals **(Brown et al., 1985).**

Winds can also cause mechanical accidents at the level of cereal crop fields summarized in the verse, in addition they play a role of vector of transmission of cryptogamic diseases, or even insect theft.

4.4.5. The climatic occurrences

Climatic occurrences are represented by hail, dew, and sirocco.

• Hail: its action is mainly mechanical, the damage is important during the flowering and maturing stages;

• Dew: its action is beneficial to plants in terms of minimizing the FTE especially at sunrise, in addition to their contribution to the water supply, but when wheat reaches the stages between epiaison and swelling of the grains, the risk of disease increases, causing the plant’s sensitivity to these stages;

• Sirocco: It is considered harmful to the plant its action is physiological.

It is defined by very active sweating when excessive temperatures appear. These have the consequences of an imbalance in the development of cereals during the two sensitive phases of epiaison and maturation.

CONCLUSION

The main objectif in this memory was knowing the contribution of geomatic for synthesis and for forecasting cereal diseases, through the remote sensing method which works on the collection and processing and retrieval of environmental information in earth, and know the climate projection models.

So, cereal diseases can be grouped according to the symptoms they induce and the parts they affect. And also there're methods for control can be chemical, cultural, genetic, and the control of cryptogamic diseases in wheat is intended to minimize and delay the development of diseases, to prevent them from reaching the upper leaves that contribute than more 50% to grain filling.

Also we should to know the effects of climate change on wheat diseases because climate change and especially the increase in global temperatures are expected to reduce of the yields of the major cereal crops, to ensure food security, the important role of the genotypes that can withstand on-going climate changes needs highlighting.

The geomatics and geographic information system having methods are statistical,analytical, and descriptive methods, they make it possible to materialise agro-climatic regionalization in different forms, These methods must be implemented to increase crop yields and achieve food security.

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