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Describing and predicting of the vegetation development of Corsica due to expected climate change and its impact on forest fire risk evolution

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ABSTRACT

Among the consequences pointed out by the Intergovernmental Panel on Climate Change (IPCC), it is assumed that xeric and thermophilic ecosystems, which are mostly involved in forest fires, could colonize areas currently less or not exposed to forest fire risk. The aim of our study is to assess the spatial distribution of xeric and thermophilic botanical taxa in Corsica for the end of the 21st Century, according to the climatic scenario named RCP 6 which is considered as one of the most probable reference scenario. The results of our study show a probable increase of forest fire risk due to the colonization of xeric and thermophilic ecosystems in more areas than we can observe today.

1. Introduction

The fifth report of the Intergovernmental Panel on Climate Change (IPCC, 2014) has presented scenarios of increasing average temperature between 1.4 °C and 3.1 °C (baseline 2.2 °C) over a period of 100 years. This climate change is expected to have particular consequence of a gradual change in ecosystems, which would affect the nature and distribution of the constituent species of these ecosystems and, in the same time, it would bring changes in the functioning of these ecosystems. Expected evolutions include changing the geographical boundaries of the current Mediterranean bioclimatic zone (*sensu lato* Mediterranean), particularly north of this area and in upland areas. Mediterranean plants could in no case follow latitudinal displacement of their potential range at the rate advertised. They could possibly keep high in the high thermal gradient hills, provided they are already present in the area (Vennetier and Ripert, 2009).

The main models of vegetation distribution include few species, mostly woody, or functional groups of species for certain types of plant formations. Works of American foresters and French researchers (Badeau et al., 2004; Thuiller, 2003; Thuiller et al., 2006; Iverson et al., 1999) are based on the juxtaposition of botanical observations and climate measures respectively located in grids ranging from 10 to 50 km on each side, according to the different studies. The results are indicative woody plants of the climate based on geometric model (mainly based on correlations) which takes into account neither the intermittent nature of botanical observations, nor the ordinal nature of the relationships between plants and climates. Garbolino et al. (2007) proposed a probabilistic method to quantify the relationship between 1874 woody and herbaceous plants and 72 climatic variables measuring the average monthly climate over a period of 50 years in France. The results of this climatic calibration provided a catalogue of bio-indicators of climatic patterns, the fundamental basis that should be reversed and complemented with new data for modelling the distribution of vegetation on French territory. A preliminary research was conducted within the project Proterina C for 40 plants species in Corsica. This research has identified the territories colonized by species potentially involved on forest fires in Corsica within 2100 (Garbolino, 2010).

Other vegetation types currently in place in the extension areas of the Mediterranean climate are by nature much less resistant to drought and high temperatures, the future climate will lead to very high levels of water stress and dieback (Allen et al., 2010). These two factors make any vegetation particularly flammable and combustible and therefore increase the risk of fire. Indeed, the Climate Change report also indicates the possibility of increasing risks of phenomena such as forest fires due to increased mortality of woody taxa but also because of the specific modification of ecosystems with currently few species adapted to drought, heatwaves and fires. Roman-Amat report (2007) underlined potential shifts

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in vegetation which should be anticipated to prepare French forests to climate change.

The evolution of vegetation and species spatial distribution with climate change also raises questions about the future evolution of urban development next to fire prone natural areas. In the Mediterranean region, fire risk is still increasing (Alexandrian et al., 1998), with a higher fire frequency expected due to climate change and land abandonment leading to fuel accumulation (Piñol et al., 1998; Cramer, 2001; Pausas, 2004). From climate change forecast (Jacq, 2008) and land-use dynamics (Léon, 2008), Rigolot (2008) infers an increased fire risk in already fire-prone areas but also in new territories. Peri-urban areas are among the main concerns. These interfaces between rural and urban areas (WUI for Wildland Urban Interface) are particularly exposed to forest fire.

The main question is how to identify the evolution of vegetation spatial distribution until 2100, especially the species involved in forest fires, in order to anticipate the exposition of the territory to forest fire and to estimate the level of risk for the population.

We propose to present this problematic through Corsica, as case study. We first present brief issues about Corsica and its level of risk generated by wild fires. Then, we present the methodology to assess the potential exposition of Corsica to forest fire taking into account the previous scenario of global warming within 2100.

2. A brief presentation of the territory of Corsica

Corsica is an island in the Mediterranean Sea, with mountainous landscapes and a high geological diversity. A large granite massif is situated in the western and southern territory (two third of the island) with the highest peaks (Cinto 2700 m; Rotondo 2600 m). The north-eastern Corsica called "*Alpine*" is composed by shales, with peaks over 1000 m, a rugged relief, very close to the littoral area. These two geological entities are connected by a central depression, with an altitude that not exceeding 600 m, the central sulcus of Corte. At the East are situated plains (Aleria), at the North, limestone areas (Saint-Florent) and at the far south, the tray of Bonifacio. Because of this rugged topography, road communications are difficult and it takes time to move through the different parts of Corsica.

Concerning the vegetation, Corsica is the most wooded islands in the Mediterranean, with a lot of remarkable natural environments, from the littoral zones to the mountain peaks. According to the inventory of the IFN (National Forest Inventory) in 2014, 79% of the territory of the island is covered by vegetation, composed by forest (58%), heathland, scrub and woodland (26%).

Because of the presence of vegetation in most of the part of the island, the inhabitants are exposed to forest fire. According to the French Institute of Statistics (INSEE), the demography of Corsica has a continuous growth: in 1851, Corsica had 236,251 inhabitants and this number is of 322,120 in 2013. The rate of evolution was +0.9% from 1982 to 2011 and +1.3% from 2006 to 2011, which indicates an increase of this rate since the last decade. In 2011, the total of population was of 314,486 people and this total was of 322,120 people in 2013 and 323,092 in 2014, with a last rate of growth around of 1.003%. This rate of population growth is one of the highest rates in France.

But the repartition of the population is not homogeneous. The urban development in Corsica is characterised by a low proportion of urbanized area (about 7% of the island) with a high concentration in the coastal areas (90% of 57,000 units built, concentrated in 90% of the littoral municipalities) and a scattered urbanisation, in the remaining part of the territory.

The behaviour of the persons (inhabitants and tourists) is a factor which must be taken in account to assess the exposition of the population to forest fire risk. Corsica is attractive for many tourists, whose expectations have changed. They stay in the littoral zone, but also in the mountains (outdoor leisure and sports like hiking, canyoning, climbing...). The development of outdoor leisure and sports raises the question of the vulnerability of the natural areas and the safety of the groupings of people in isolated areas, often far away from road in extremely combustible environment, especially in summer time. In coastal areas the development of campgrounds in highly sensitive environments raises the same question of safety (Préfecture de Corse, 2007).

To study the problematic of global warming and the evolution of the exposition of forest fire risk of territories in the future, we propose to study the potential impact of climate warming on vegetation and its impact on forest fire (see Fig. 1).

3. Potential impact of climate warming on vegetation involved in forest fire: method and results in Corsica

3.1. Data on climate change in Corsica

It is widely accepted by the scientific community that global climate is getting warmer and that this warming, which seems particularly fast, will change the structure and functioning of ecosystems of our planet.

In Corsica, the study of the historical data concerning the temperatures shows an increase of 1 °C since 1950. Between 1971 and 2010, the average annual air temperature in Bastia and Ajaccio increased by 1.5 °C. If this increase in temperatures continues, the average temperature in 2050 will be 17.5 °C in Bastia and 16 °C in Bastia, values that are characteristic of the climate of Tunis (Tunisia) and Cagliari (Sicily). The climate change and the increase in temperatures have already had an impact on the rivers. For example, the flow of the river Tavignano has been halved between 1983 and 1985 (16–8 m^3). Since 1985 a deficit of this River has been measured, during 13 years out of 18 years. Period of low water in Corsica rivers now lasts 5 months. It lasted 3 months in 1984. Simultaneously, a decrease in annual rainfall has been observed since 1985 (however, the autumn rains are highest, causing a risk of flooding). The drying up of mountain lakes has become structural rather than cyclical (Conseil Economique, Social et Culturel de Corse, 2013).

The projections elaborated by DRIAS[1] show an increase in heat waves. In 2035, heat waves could occur during 5 consecutive days. In 2080, according to the scenarios of the IPCC, these heat waves could last 10–40 days, depending on the areas of Corsica. The projections of DRIAS concerning the increase in temperatures show that there would be abnormal average temperatures in summer (from +1.5 °C to 2 °C in 2035, from +4.5 °C to 6.5 °C in 2080, according to the different scenarios of the IPCC) and in winter (from +0.5 °C to 1 °C in 2035, from +1.5 °C to +3 °C in 2080, according to the different scenarios of the IPCC).

The number of nights with a temperature above 20 °C ("*tropical*" night) would be 30–65 days in 2035 and 80–85 days in 2080.

Regarding rainfall in the Mediterranean area for 2050 different models converge to a decrease in rainfall, from 4% to 27%. On the contrary, in the year 2035, a slight increase of the rainfall in mountain areas would occur, but in a context of disturbed hydrological cycle: rainfall would occur in warmer climatic conditions with higher temperatures and increased evaporation (Conseil Economique, Social et Culturel de Corse, 2013).

[1] DRIAS, the future of the climate, climatic projections for the adaptation of our societies – drias-climat.fr.

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