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Possibilities for growing queen palm (*Syagrus romanzoffiana*) in Argentina as a biodiesel producer under semi-arid climate conditions

S.L. Falasca [a,*], C. Miranda del Fresno [b], A. Ulberich [b]

[a] Institute Climate and Water, INTA, Las Cabañas y Los Reseros, Castelar, Argentina
[b] School of Humanity, CINEA, University of the Center of Buenos Aires Province, Pinto 399, Tandil, Buenos Aires Province, Argentina

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ABSTRACT

Syagrus romanzoffiana is a palm native to Argentina, where it is known by the name 'Pindó'.

This palm extends from the Misionera Forest through the gallery Forest, being the Parana Delta area the southern limit of dispersion. In this area, the large volumes of water from the rivers create a moderating effect, reducing the daily temperature range and the days of frosts.

The aim of this study was to delimit the Argentina agro-climatic suitable area for the development of this crop as a potential biodiesel-producing species, using biophysical limits observed in our country and elsewhere in the world where the plant is grown.

For a possible zoning in Argentina, agro-climatic indexes were obtained from monthly values of temperatures and precipitations from all the weather and agro-meteorological stations of the country, for the period 1971–2010. Afterward, maps with the thermal and hydric limits were superposed to define the probable areas for the crop.

1. Introduction

Nowadays, gas and petroleum are the most important energy sources in the Argentine Energy System. Due its institutional organization (open market), current dependence on hydrocarbons seems to be a result of the strategies of private agents [1].

Argentine Law N° 26.190 sets forth 8% participation of renewable energy for 2015. From the 1st of January of 2010, the National Law of Biofuels N° 26.093 established the obligatory proportion of 5% of bioethanol and biodiesel in petrol and diesel respectively. This percentage was raised to 7% by mid 2010 (Resolution 554/10) while local authorities are planning to raise it to 10% in 2012.

Argentina is the 4th biodiesel producer country, after Germany, France and Brazil. In 2010, Argentina's production reached 1900.000 tons, a 51% above 2009, with a total product value of 1900 million dollars. According to estimations, by the end of 2011 Argentine biodiesel demand will surpass the 3 millions tons, a situation that may foster new investments in order to increase the offer [2].

Beyond the discussion of the ethics of burning raw materials that could be destined to human feed, it is well known that the growth of human population will increase the energy and food demand.

The Argentinean Law N° 26.190 proposes the participation of 8% of renewable energy in 2015. Zerta et al. [3] suggest that

* *Corresponding author*. Tel.: +54 11 4621 0125/1684/1463/5663/8496.
E-mail addresses: sfalasca@conicet.gov.ar, slfalasca@gmail.com (S.L. Falasca), mc.mirandadelfresno@gmail.com (C. Miranda del Fresno), ulberich@fch.unicen.edu.ar (A. Ulberich).
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biomass potentials are limited and cannot cover the current world energy demand on its own, so land use competition for fuel and food production is a very critical issue which needs to be addressed in order to avoid distortions in food provision. For the above-mentioned reasons it is outstanding that energetic crops should be located in marginal areas, those non suitable for traditional food crops.

1.1. Characteristics and origin

Syagrus romanzoffiana is known by different common names, like 'Pindó', 'Chirivá', 'Jerivá', 'Yba Pita' and 'Queen Palm' (English). It is native to South America (SW of Brazil, E of Bolivia and Paraguay, and N of Argentina and Uruguay).

In Argentina it was recognized in the provinces of Buenos Aires, Chaco, Corrientes, Entre Ríos, San Juan, Mendoza, Formosa, Misiones, San Luis, Santa Fe and Tucuman [4].

In the early XIX century, Phytogeographical Paranaense Province covered about 100 million hectares spread across Misiones (Argentina), southern Brazil and eastern Paraguay. Currently, less than 50% of the forest remains and, today, it is the only region of Argentina with a valid and massive process of expansion of the agricultural frontier at the expense of forest stands [5]. Yet, the province of Misiones is, paradoxically, a 'relict' surrounded by areas of intense colonization, deforestation and agricultural transformation, and consequently, of deep genetic erosion for agriculture.

There, *S. romanzoffiana* (formerly known as *Arecastrum romanzoffiana*) grows. In tropical and sub-tropical cities, this palm is frequently used as part of urban trees. This is probably the best-known palm tree in the world.

In its natural habitat in Argentina, *S. romanzoffiana* grows close to large rivers, being its southern limit of dispersion the Delta of Paraná River, on the border with Uruguay, although it has also been recognized in ravine, hilly and coastal shrub lands. This is the reason why there is a large phenotypic variation within this species, being able to grow in dry inland areas of the country as well as in humid conditions.

From time to time, in the Delta area, the elegant Queen Palms, which have given the name to the Paraná de las Palmas, a tributary of the Paraná River, protrude from the forest canopy.

From the biogeographical point of view, the Paraná Delta region is considered a subtropical ingression (the Chaco and Paranaense or Misionera regions) in a temperate zone (the Pampas), which allows the coexistence of typical species of both areas and gives the region a differential profile, forming a typical pattern of plants and animals [6,7].

This palm grows to 20 m tall. The stipe is straight, ringed and grayed. The foliage is persistent, deep green and bright. The leaves are pinnately compound. The flowers are yellow and arranged in an inflorescence, protected by a woody spathe. Each inflorescence weighs about 10 kg (dry weight). It blooms in spring and summer. The fruit is an elliptical drupe, uni-seminated, reddish yellow, fibrous, of 1 cm in diameter. The seeds germinate easily. It fructifies in summer and autumn.

The Queen Palm is presented as a promising crop for Argentina, as feedstock to produce biodiesel, due to its high drought tolerance and its resistance to moderate frosts.

1.2. Uses and yields

The fruits are edible and have an important role in the ecosystem because they are consumed by frugivorous species [8]. The fruit pulp is valued by humans, pigs and other animals [9]. While fruits and leaves serve as food for cattle [10], the bracts are used for handcraft work.

In the N of Argentina it blooms almost throughout the year, which allows its use for honey production. Its fruits can be used for oils extraction for biofuel production and/or expeller.

The seed has 25%–52% of oil. The oil contains mainly oleic and lauric acids. It is colorless and has a low acidity index, with a viscosity of 15.5 cSt [11].

Oil can be easily converted into biodiesel, either by the base saturation method or by the modified method. Both methods allow the conversion of oil into biodiesel with a conversion efficiency ranging from 105 to 111%.

The Queen Palm is used in rustic buildings, due to its moderately heavy, hard and highly durable wood [12]. It produces a good quality and slightly bitter palm heart [13], being one of the species listed for production of this type of food [14].

The seeds of the green fruits germinate more slowly and in a lower percentage than the seeds of yellow or red fruits. The speed of germination for the seeds of the yellow or red fruits does not significantly differ among themselves. For scarified seeds, regardless of the stage of maturity, the germination percentage is significantly higher and this process is significantly faster compared to not scarified seeds [15].

While a number of papers discuss about the commercial exploitation of palm trees to extract oil and fiber [16], the potential of palm trees as source for new and biodynamic uses has received little attention.

In Argentina there is a marketing program for the use of palms with ornamental purposes, being the 'areca palm' (*Dypsis lutescens*) the top seller, followed by others, such as Queen Palm, which are exported to European countries, like Spain, France and Italy [17].

1.3. Ecological requirements

The seed requires high temperatures to germinate. The highest percentages of germination were observed at constant temperatures of 30 °C and 35 °C. However, there were no statistical differences with temperatures ranging from 25 to 35 °C [18].

In the growing season, the Queen Palm requires a lot of moisture and frosts in winter are moderately well tolerated if daytime temperatures are mild. It is resistant and easy to transplant. Therefore, its use in avenues and parks of Argentina as an ornamental plant has spread widely. It grows in a wide range of soils from the coastal sands to heavy clay soils with cracks.

The southern limit of dispersion in Argentina is the area of the Parana Delta, where the average annual temperatures are around 16.7 °C, with an annual precipitation of 1073 mm and 79% of relative humidity. There, the large volumes of water from the major rivers and the large flooded areas of floodplains generate a moderating effect. This determines

a reduction in the daily range of temperatures and in the number of frost days due to an increase of minimum temperatures and a decrease of maximum temperatures.

The mean minimum temperature that can be expected in this region is an important factor to consider when choosing a palm to place in a particular area. The minimum temperature that it can support depends on a variety of factors, such as humidity, size and age of the palm, the evolution of high temperatures during the day and the time the temperature is maintained at the minimum value. Protection measures from frost are recommended until the palm reaches about 1.5 m high.

The Queen Palm prefers hot summers for optimal growth. Its strength and hardness to low temperatures allows it to tolerate about −8 °C, although it may also be interesting to consider the duration of the frost. Thus, temperatures of −5 °C for several days will make much more damage to the Queen Palm than a nocturnal decrease of −8 °C for 1 h or less [19].

Cold weather can affect the palm in several ways. It reduces the growth of the apical bud and root growth becomes slow. This reduction of activity may weaken it to the point that illnesses can represent a serious problem and they can even kill the plant. Severe damage caused by frost can destroy the tissues. Even the destruction of the stem tissue can seriously reduce the water supply for several successive years. Therefore, when the warm season returns, the disease-causing agents can attack more easily the weakened palm trees.

Because of its very fast and invasive growth, this palm is often treated as a weed in large part of Florida. Mature specimens have survived to short periods at temperatures of −10 °C. In these cases, complete defoliation has been registered, and some trees have also been killed. It is widely cultivated in the city of Rockhampton, where the temperature is several degrees below freezing and the ranges of precipitation oscillate from 400 mm to 2000 mm per year [20].

They perfectly support the excess of moisture in rainfall regimes with 1500–2000 mm per year and 90% of environmental humidity.

The Queen Palm produces fruits throughout the year if there is a good water supply. In other situations, it fructifies twice a year.

2. Experimental

Requirements, limits and bio-meteorological tolerances of the species, depending on the characteristics of the area of origin, were first identified. In parallel, to proceed to the agro-climatic assessment, an agro-climatic inventory was performed based on information from the Weather Statistics and derived agro-climatic values. For a possible zoning in Argentina, agro-climatic indexes were obtained from daily values of temperature and precipitation from all the weather and agro-meteorological stations in the country, for the period 1971–2010.

Then, the average annual isohyets were mapped, giving especial attention to the isohyet corresponding to 400 mm to define the appropriate growing area, according to the minimum requirement of water.

To determine the thermal limits for the classification of an area with suitable aptitude, it was considered an annual average temperature above 16.7 °C.

Consideration was given to the absolute minimum temperature of −8 °C, which can be expected to occur with a probability of 5% ($p = 0.05$), a value that represents the tolerance of the species at low temperatures.

The overlapping of the previous maps allowed defining the agro-climatic suitability for the growth of Queen Palm in Argentina.

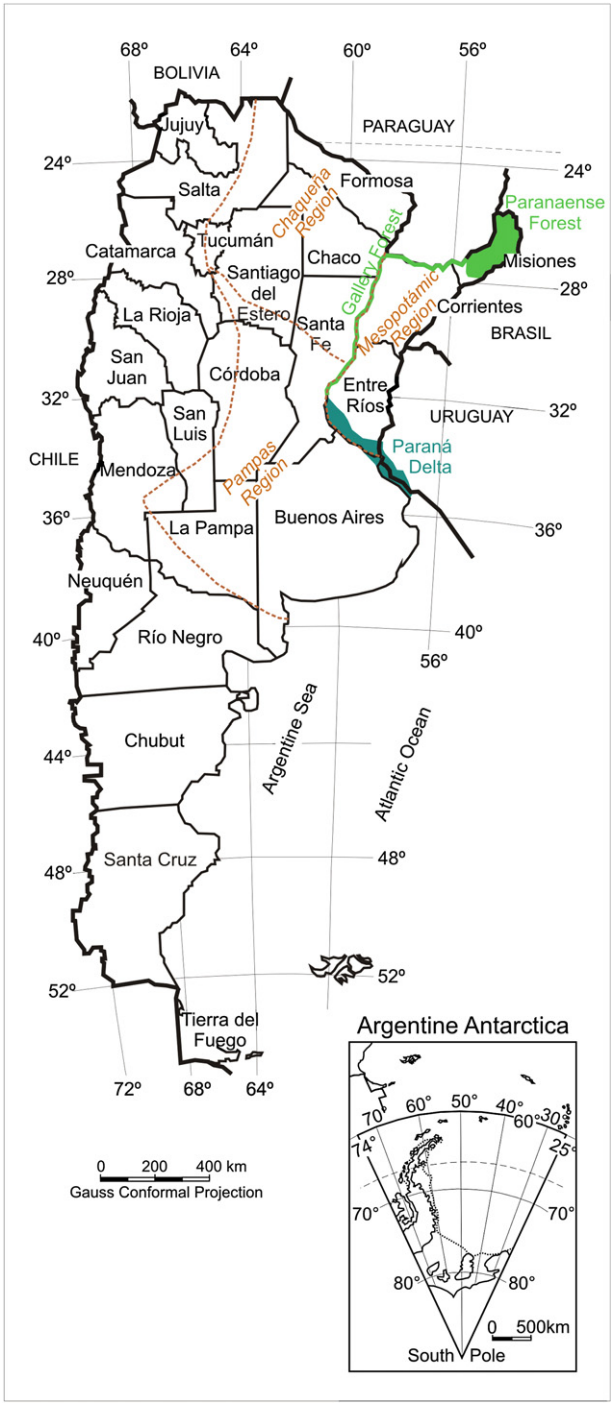

Fig. 1 – Political map of Argentina.

For a better interpretation of the results, the names of the provinces and the limits of the phytogeographical regions cited in this paper are indicated in Fig. 1.

3. Results and discussion

Fig. 1 shows the political map of Argentina with the phytogeographic limits cited in the text.

As shown below, Figs. 2–4 indicate the spatial variation of the geographical limits for the different variables that define the suitability classes.

Finally, Fig. 5 shows the agro-climatic suitability for the cultivation of Queen Palm for energy production in Argentina.

This figure shows the *optimal* growing area, which covers most of the Argentinean northern provinces. It includes all the Mesopotamia, the whole provinces of Formosa and Chaco, E and central Salta, Tucuman, E of Jujuy, eastern part of La Rioja and Catamarca, NW and NE of San Luis, central W and NE of Cordoba, N, E and W of Santiago del Estero, almost all Santa Fe, except the SW area, a small part of Mendoza and N of Buenos Aires.

To the S of this sub-region there is another area classified as *suitable with thermal limitations*. This area covers the rest of the province of Santiago del Estero, most of Córdoba, SE of Santa Fe, part of the provinces of San Luis and Mendoza, NE of La Pampa and NW of Buenos Aires.

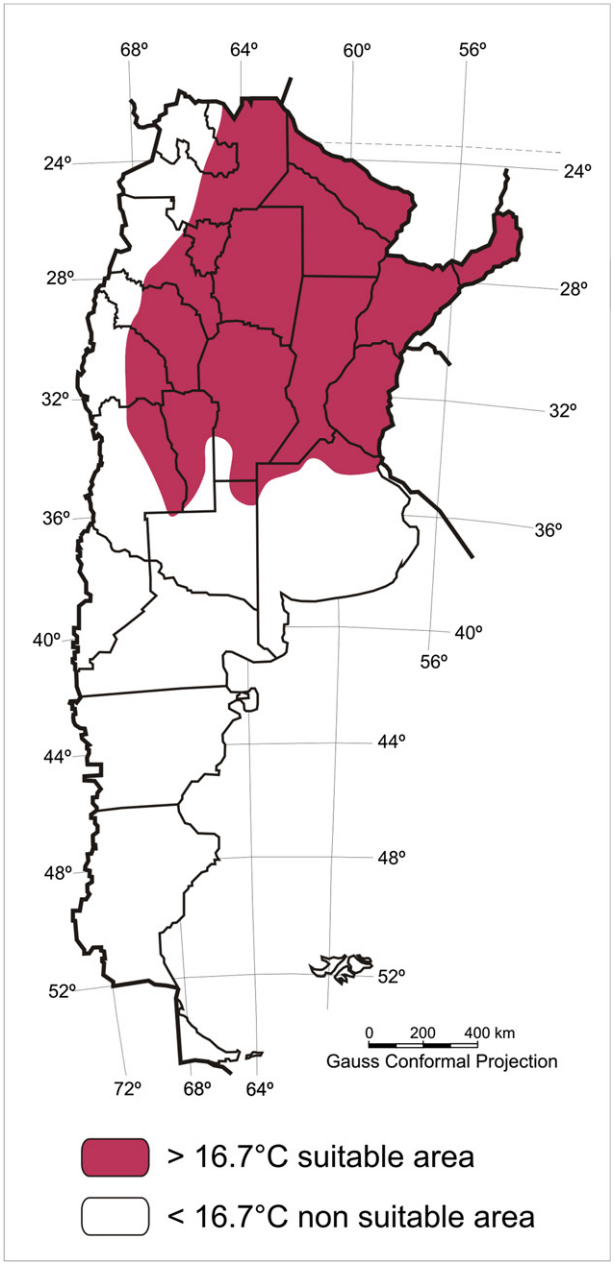

Fig. 2 – Mean annual temperature.

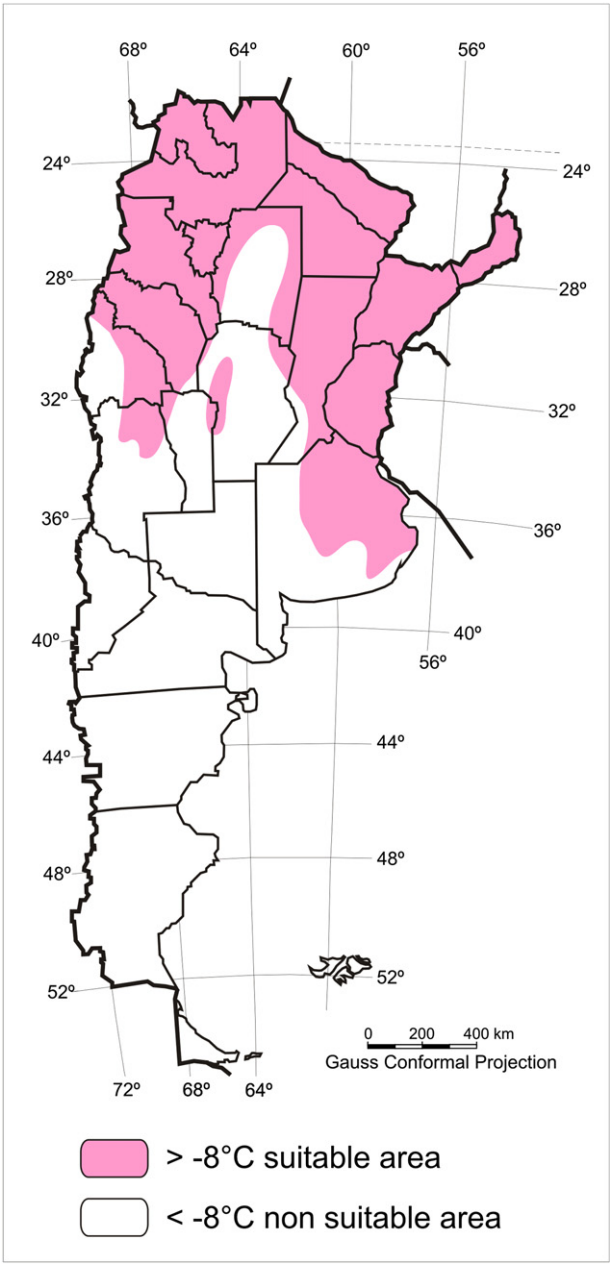

Fig. 3 – Absolute minimum temperature to expect 1 every 20 years ($p = 0.05$).

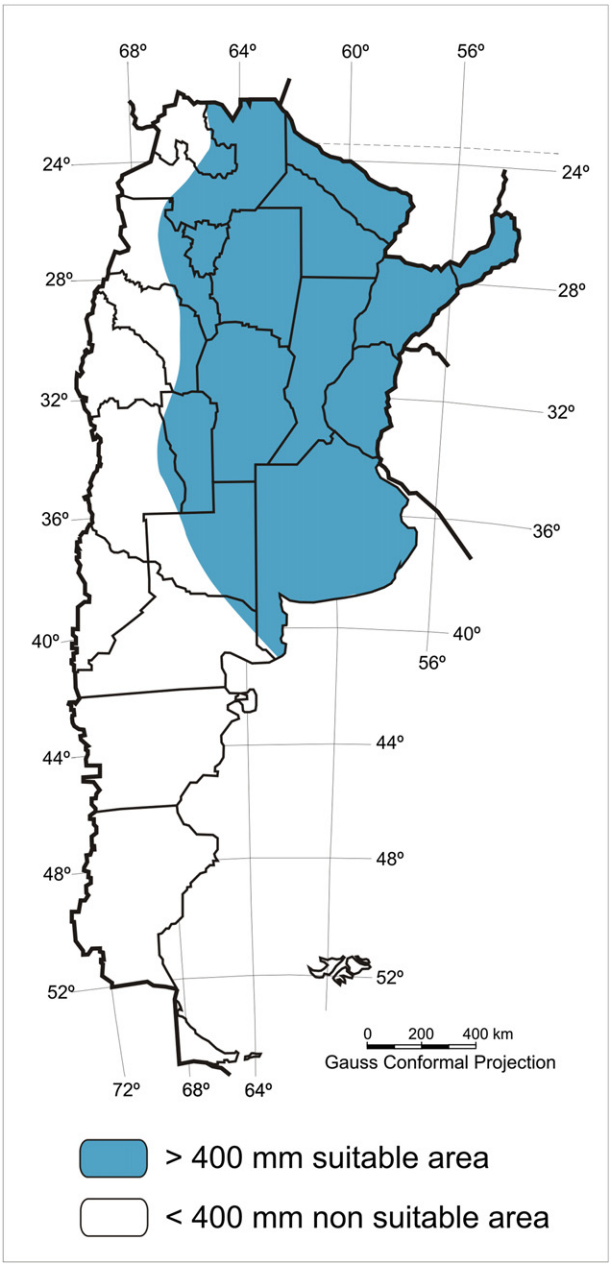

Fig. 4 – Mean annual precipitation.

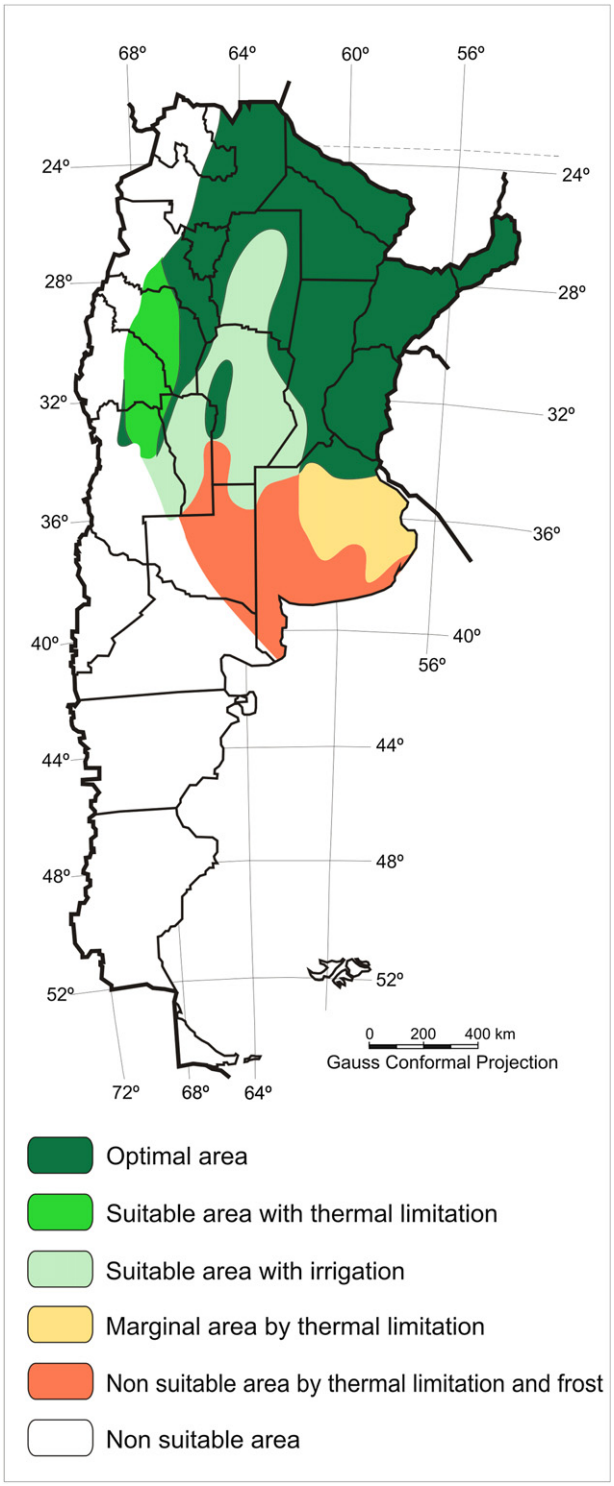

Fig. 5 – Agro-climatic suitability for the cultivation of *Syagrus romanzoffiana*.

Despite its agronomic importance, the trees, palm trees and shrubs native to Argentina have been only partially integrated to the agricultural production systems.

Reforestation with Atlantic forest native species, as *S. romanzoffiana*, in the area qualified with optimal suitability, which has been occupied by agriculture or other anthropogenic activities, may allow recovering, in part, the altered natural ecosystem.

In the Paraná Delta, the fruit and vegetable production that was present a couple of decades ago was replaced by forestry (although less demanding of manpower and technology, it introduced in some areas the environmental risks of monoculture).

In the province of Misiones, as happens in most of the world's forestation, planting trees in deforested regions generates monospecific ecosystems. They are usually constituted by exotic species and specimens of similar ages, which in any case do not replace the original ecosystem where there was a great biodiversity.

Forestry with Queen Palm for the production of oil and other sub-products, will be more favorable to maintain the

biodiversity in the province of Misiones, in the Paraná Delta region, and in areas under sub-humid weather conditions, than any exotic species.

4. Conclusions

The existence of a large area with suitability for the cultivation of *S. romanzoffiana* has been demonstrated. It is feedstock to generate melliferous activity, produce oil and other sub-products.

It is recommended to growth this palm under wet weather conditions in deforested areas, where it will not change the biodiversity and will help to restore the altered natural ecosystem. It is also recommendable for areas with sub-humid climate where this species will not constitute an environmental threat, because it is unlikely to transform itself into a weed or plague since it is endemic to Argentina.

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